GENERAL SPECIFICATIONS

FOR

CONCRETE BRIDGES

BY

WILBUR J. WATSON

Civil and Architectural Engineer

SECOND EDITION

1910

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"Bridges ought to have the self-same qualifications we judge necessary in all other buildings, which are, that they should be commodious, beautiful and lasting."

—Andrea Palladio.

Preface to the Second Edition, 1910

Since the publication of the first edition more than two years ago, the Special Committee on Concrete and Reinforced Concrete, of the American Society of Civil Engineers, acting jointly with similar Committees of the American Society for Testing Materials, American Railway Engineering and Maintenance Association, and the Association of American Portland Cement Manufacturers, has made a progress report which has been adopted by the Society. The Author of these specifications has endeavored to adjust the notation, allowable stresses, etc., used in this work, to those used by the Committee, as far as he consistently could. On the other hand he has stuck to his own ideas and methods wherever, in his judgment, they give better results than those recommended by the Committee.

There has been much progress in the art during the past two years, and the author has endeavored, in revising these specifications, to bring them up to date.

The concentrated loads for Classes G and H Bridges have been reduced, and an effort has been made to make all designing rules more definite, and, where possible, more simple.

The text has been considerably enlarged and some additional data included.

WILBUR J. WATSON.

August, 1910.

Preface to First Edition

The Author believes that these specifications will meet an actual need of the profession, and that no further apology is necessary for their publication.

While most of the clauses represent ideas gained from personal experience, many of them have been obtained from published articles in the engineering press, from suggestions made by other Engineers, etc., and the writer wishes to especially acknowledge his indebtedness to the valuable experiments conducted by Prof. Arthur N. Talbot at the University of Illinois.

The Author believes that these specifications will be found especially useful in cases where they are made the basis of competitive designs, as in that case it will be possible to compare all such designs on an equal basis.

In using these specifications, it should always be borne in mind that many clauses, and especially those giving instructions for designing and proportioning, must be modified to suit different conditions, and different materials than those assumed.

The Author cordially invites criticism of these specifications.

WILBUR J. WATSON.

January, 1908.

Watson's Specifications for Concrete Bridges

INDEX TO SECTIONS

General Specifications for Concrete Bridges

CLASSIFICATION AND LOADS

1. *Concrete Bridges* will be divided according to use into the following classes:

Class A.—Heavy Railroad Bridges.
Class B.—Light Railroad Bridges.
Class C.—Heavy Electric Railway Bridges.
Class D.—Light Electric Railway Bridges.
Class E.—City Highway Bridges carrying Electric Railway tracks.
Class F.—City Bridges without Electric Railway tracks.
Class G.—Suburban Bridges carrying Electric Railway tracks.
Class H.—Suburban Bridges without Electric Railway tracks.
Class I.—Light Country Bridges.
Class J.—Foot Bridges.

2. *Concrete Bridges* will be divided according to design into the following types:

(1) Circular and box culverts.
(2) Slab bridges.
(3) Deck beam bridges.
(4) Through girder bridges.
(5) Arch bridges.
(6) Cantilever bridges.
(7) Truss bridges.
(8) Viaducts.

3. *Bridges* will be *designated* by reference to class and type; thus a city highway arch of 60 ft. span and carrying Electric Railway tracks, will be designated as a Class E Arch Bridge.

4. *Class A Bridges* will be designed, unless otherwise specified, for Coopers E 60 loading and will be used for all railroads carrying heavy traffic, hauled by locomotive power.

5. *Class B Bridges* will be designed, unless otherwise specified, for Coopers E 40 loading and will be used for railroads carrying light traffic, hauled by locomotive power.

6. *Class C Bridges* will be designed, unless otherwise specified, for two 100 ton (200,000 lbs.) cars entrain, wheel base 6 feet, 22 feet c to c of trucks, and will be used for Electric Railways carrying very heavy traffic.

7. *Class D. Bridges* will be designed, unless otherwise specified, for two 50 ton (100,000 lbs.) cars entrain, wheel base 6 feet, 22 feet c to c trucks, and will be used for Electric Railway bridges carrying light traffic.

8. *Class E Bridges* will be designed for (a) a concentrated live load of twenty-four tons (48,000 lbs.) on two axles, ten (10) foot centers and five (5) foot gauge, assumed to occupy a width of (10) feet; and (b) a uniformly distributed load of one hundred and twenty-five (125) lbs. per square foot on all roadways and footwalks. The Street Railway tracks will be assumed to carry the loads specified for Class D Bridges.

9. *Class F Bridges* will be designed to carry the concentrated and uniformly distributed live loads as given for Class E.

10. *Class G Bridges* will be designed to carry a concentrated live load of eighteen tons (36,000 lbs.), and a uniformly distributed live load of one hundred (100) lbs. per square foot of roadways and footwalks arranged as for Class E Bridges. The Street Railway tracks will be assumed to carry the loads specified for Class D Bridges.

11. *Class H Bridges* will be designed to carry a concentrated live load of fifteen tons

(30,000 lbs.) and a uniformly distributed live load of one hundred (100) lbs. per square foot arranged as for Class E.

12. *Class I Bridges* will be designed to carry a concentrated live load of twelve tons (24,000 lbs.) and a uniformly distributed live load of seventy-five (75) lbs. per square foot arranged as for Class E.

13. *Class J Bridges* will be designed for a uniformly distributed live load of seventy-five (75) lbs. per square foot.

14. Bridges designed for other loads than given herein will be classed *special* and that letter shall be used to designate them which is used herein to represent that class to which they most nearly conform; thus an electric railway bridge designed for 60 ton cars would be designated as Special Class D.

15. An addition will be made to all stresses caused by concentrated live loads to cover the effects of *impact*, vibration, etc., which will be determined in the following manner:

For Classes A and B; Impact $= S\frac{300}{L+300}$, and for Classes C and D; $I = S\frac{225}{L+300}$

For all other Classes $I = S\frac{150}{L+300}$

where I = impact to be added to the liveload stress.

S = calculated maximum live load static stress.

L = length of loaded distance in feet which produces the maximum stress in the member.

16. The above impact formulas are to be used when the concentrated loads are carried directly upon the structure. When there is provided a cushion of sand, or an equivalent between the pavement or ties which carry concentrated loads and the structure itself, the impact stresses may be reduced 20%, and 10% additional for each foot of such earth or sand cushion.

17. The sign + will be used to indicate compressive, and the sign —, tensile stresses.

18. When the live load stress is of an opposite sign to the dead load stress, then the impact shall be assumed to be in all such cases equal to the live load stress, and in case of reversal of stress by live load the member shall be proportioned for a stress equal to the sum of the greater and one-half the lesser maximum stresses.

19. *Wind pressure* shall be assumed at 50 lbs. per square foot on one and one-half times the vertical projection of the structure unloaded, or 30 lbs. per square foot on the same surface; plus 400 lbs. per lineal foot, applied 7 feet above the rail, for assumed wind load on train when the structure is either fully loaded or loaded on either track with empty cars (assumed to weigh 1,200 lbs., per lineal foot), whichever gives the larger stresses.

20. Classes A, B, C and D bridges will be computed for a *lateral force* on the loaded chord of 200 lbs. per lineal foot plus 10% of the specified train load on one track, and 200 pounds per lineal foot on the unloaded chord, these forces being considered as moving.

The lateral force will be used for lateral systems only and will be considered as replacing the wind load given above, when giving larger stresses.

21. When the structure is on a curve the *Centrifugal Force* must be considered and calculated, for all classes carrying tracks, by the formula,

C = 0.03 W D for curvature up to 5° D = degree of curvature.

Where C = Centrifugal force in lbs. W = weight of train.

The co-efficient for centrifugal force (0.03) shall be reduced 0.001 for every degree of curvature above 5°.

22. The effect of suddenly *stopping* the moving loads must be considered; the co-efficient of friction of wheels sliding upon the rails being assumed at 0.2.

Assumptions for Computing and Designing

✓ 1. The weight of *Reinforced Concrete* shall be assumed to be, per cubic foot, for stone or gravel concrete, 144 lbs.; for average slag concrete, 132 lbs.; unless the precise weight of the material to be used be determined by weighing.

2. The weight of *Tracks* shall be taken at 250 lbs. per lineal foot for ballasted construction, and 400 lbs. per lineal foot for timber deck construction.

3. The weight of *Ballast* for classes A, B, C and D shall be assumed at 1,200 lbs. per lineal foot of track with subgrade 21 inches below top of rail and 14 ft. wide for single track and 27 ft. wide for double track.

4. The weight of *Earth Fill* shall be assumed at 100 lbs. per cubic foot.

5. The weight of *Timber* shall be assumed at 4 lbs. per foot B. M. if untreated or 5 lbs. if creosoted.

6. The weight of *Brick or Stone Paving* shall be assumed at 144 lbs. per cubic foot; of *Asphalt* 136 lbs. per cubic foot.

7. The weight of *Sand* Filler shall be assumed at 120 lbs. per cubic foot.

8. The *Concentrated Loads* for locomotive and motor wheels may be considered as *distributed* over five (5) feet of track, but the concentrated loads specified for roadways must be considered as carried at a single point on the pavement surface. (See ¶ 11.)

9. The load on railroad or electric railway tracks shall be considered as distributed over a width equal to the length of tie used, except when a fill of over 8 feet is used, when the load may be considered as distributed over a width equal to the spacing of the tracks, or in the case of single track, the angle of distribution of pressure may be taken at 30° with the vertical at the ends of the ties.

10. The angle of distribution of concentrated loads on concrete may be assumed at 45°. Thus a concentrated load on a concrete slab having a depth of one foot from surface of concrete to reinforcing steel may be considered as distributed over four square feet, in figuring the tension in the steel.

11. The minimum area of distribution for all concentrated loads on reinforced concrete slabs *reinforced in both directions* as herein specified may be assumed at 9 square feet, 3 feet in each direction.

12. In the case of stringers for highway bridges and similar cases, the maximum concentrated loads on any stringer may be assumed to be the total concentrated load which can be placed directly over that stringer, multiplied by the distance between the stringers, and divided by the gage or distance apart (measured at right angles to the line of the stringers) of the concentrated loads.

13. The *Length of Span* for Reinforced Concrete beams, girders and trusses shall be considered to be the clear distance between supports, without any allowance for corbels which are of less depth than the beams or girders which they support. When corbels are of greater depth than the beams or girders which they support, the span may be taken between the points at which the depth of the corbel equals the depth of the beam or girder. Slabs shall be assumed to be shallow beams.

14. The *Length of Span* for arches shall be considered to be equal to the span of the neutral axis of the arch ring, measured from the point where it intersects the vertical to the tangent to the curve at the spring point of the intrados.

15. The *Rise* of the arch shall be assumed to be the distance from the line connecting the ends of the neutral axis to the neutral axis at the crown.

16. The above definitions for Span and rise of Arches are for computing purposes only, the Span and rise shown on drawings shall be the *clear span* between springing lines and the *clear rise* to the intrados of the arch.

17. All slabs, beams and girders of monolithic construction shall be considered, unless otherwise shown on the drawings, to be *Partially Continuous* and shall have reinforcing in the upper part of the beam at the supports.

18. At intermediate supports of continuous beams, girders and slabs, the reinforcement for the negative bending moment must equal two-thirds of the reinforcement required at the section of maximum positive moment.

19. At the end supports of continuous beams, girders and slabs, the reinforcement for the negative bending moment shall equal 33 per cent of the reinforcement required at the section of maximum positive moment.

20. The bending moment due to external forces shall be determined by the usual methods for simple beams; and for partially continuous or restrained beams the maximum positive bending moment shall be taken at 8-10 the corresponding moment as determined for simple beams, and the maximum negative moment at intermediate supports shall be taken at two-thirds the maximum positive moment, and at end supports it shall be taken at one-third the maximum positive moment.

21. The reactions for partially continuous beams shall be taken at 1¼ times the reactions for simple beams at all intermediate supports and as equal to the reaction for simple beams at end supports, and in calculating web stresses, and providing reinforcing members to resist same, this increase shall be taken fully into account.

22. In the case of *Square Slabs* reinforced equally in both directions, the bending moment at the center of the slab in each direction shall be taken at one-half that for slabs reinforced in one direction only.

23. In the case of *Rectangular Slabs* having one side longer than the other, but not exceeding one and one-half times the length of the other side, the loads may be considered as carried to each side if the reinforcing be designed to properly distribute the loads to the four sides.

24. When loads are considered as carried to four sides of a square or rectangular slab as above, the negative bending moment over the supporting beams must be increased 50 per cent over that for slabs, reinforced one way; and in the case of rectangular slabs, the unequal distribution of the panel loads between the beams must be considered.

25. Allowance must be made in proportioning column for the *Contraflexure* caused in the case of monolithic construction by the full live load occupying one panel and no live load in the adjacent panels, and the moment over the supports will be assumed to be divided between the girder or other member carrying such load to the column, and the column, in proportion to the squares of their respective effective depths. By the effective depth of the column is meant the effective depth considering the column to act as a beam to resist flexure.

26. In addition to the preceding requirements the effect of *Eccentric Loading* must be fully taken into account.

27. All tensile stresses will be considered to be resisted entirely by the steel reinforcing, no allowance will be made for concrete in tension.

28. The *Stress-Strain Curve* of concrete in compression will be assumed to be a straight line.

29. The ratio of the *Modulus of Elasticity* of steel to that of concrete shall be taken as equal to 15 for stone and gravel and slag concrete and 30 for cinder concrete and to be constant within the limits of the allowable range of stress.

30. A plane before bending shall be assumed to remain a plane after bending.

31. Initial stresses in concrete and steel due to shrinkage of concrete in setting shall be neglected.

32. In the computation of the resistance of T beams the portion of the slab that may be assumed to assist in compression shall be limited so that in no case shall the projecting part of the slab portion exceed in width 4 times the thickness of the slab, and the total top width shall not exceed four (4) times the thickness of the stem, or ¼ the span of the slab or of the beam.

33. When the thickness of the slab portion or flange of T beam is equal to or greater than .35 the depth of the T beam, the moment of resistance, etc., shall be determined in the same manner as for a rectangular beam.

34. When the thickness of the slab portion is less than .35 the total depth of the beam, the increased compression in the slab must be taken into account, and the ratio of steel area in tension to the area of the enclosing concrete rectangle, must be reduced.

35. When the thickness of the slab portion of a tee beam is less than one-fifth (1-5) the depth of the stem, fillets shall be used at the juncture of slab and stem, the thickness of which at the stem shall be not less than one-fifth (1-5) the depth of the stem and such fillet shall extend, when possible, to the limits of the slab portion of the tee beam. The slab part of tee beams must be placed at the same time and be composed of the same material and class of concrete as the stem.

36. In designing partially continuous T beams the compression in the lower portion of the stem at point of maximum negative moment must be computed and if it exceeds the maximum allowable unit stress on concrete sufficient reinforcement must be provided to take up the excess stress.

37. The concrete must be able to transmit the entire shear from a beam into its connections without any reliance upon the shearing resistance of the steel bars unless the reinforcing be of such a character that it will transmit the shear in itself without reliance on the surrounding concrete, in which case it may be considered to carry the entire amount of shear which it would be capable of carrying were it not encased in concrete.

38. Whenever the unit web tensile stresses on concrete exceed the allowable unit stresses as given herein, steel stirrups must be used to provide for the excess tensile stresses or part of the rods must be bent up in such a manner as to provide the necessary resistance, but in the latter case care must be taken to leave enough rods in the lower portion of the beam at the ends to provide the required adhesion, and, if necessary the straight bars shall be anchored at the ends.

39. In reinforcing to provide resistance against web tension, diagonal bars rigidly attached to the main reinforcing bars in such a way as to transmit the full strength of the web bar into the main bar without distortion of the connection, shall be preferred. The web bars designed in this way and having a length above the neutral axis sufficient to develop the full strength of the member by adhesion and having all bends of sufficient radius to prevent overstraining the concrete at

the bends, may be stressed to 16,000 pounds or the same unit stress as used for the main tension bars.

40. Vertical stirrups which pass under the main bars or diagonal stirrups which are subject to shearing stresses at the connections to the main bars shall be stressed to only ¾ the unit stress allowed for main reinforcing bars.

41. Web reinforcing bars shall be spaced a distance apart not exceeding the effective depth of the beam for diagonal members or ½ the depth of the beam for vertical members.

42. When the main reinforcing bars are bent up at the ends to provide resistance against web tension, such bars may be counted at their full strength provided that the bends are not less in radius than eight times the diameter or side of the bar and that sufficient length is provided above the neutral axis to develop the full strength of the bar by adhesion.

43. For simple beams uniformly loaded the shear intensity shall be considered as being a maximum at the supports and decreasing uniformly to zero at the center. For continuous beams uniformly loaded the shear shall be considered uniform to a point ¼ of the span from each end and then decreasing to zero at the center. For beams loaded with concentrated loads the distribution of shear shall be assumed to be the same as that which occurs in the simple beam, for both simple and continuous beams.

44. No reliance shall be placed on concrete for resistance to diagonal tension when the diagonal tension exceed three times the unit stress allowed, but sufficient web reinforcing shall be provided throughout the length of the beam, to provide for the entire web tension.

45. All reinforcing bars must be of sufficient length to develop the full stress in the bar at all points without exceeding the allowed unit stress of adhesion of concrete to steel, or proper anchorage must be provided.

46. Care must be taken to insure that all reinforcing bars over supports have sufficient length to develop their full tensile strength by adhesion, outside of all filletts, etc.

47. When bars are anchored in concrete by bending, the radius (r) of the bend shall not be less than eight times the concave side or diameter when the unit stress in the steel is 16,000 lbs. per square inch or a proportionate radius for other unit stresses. When bars are anchored by bending to radius less than this, the bars shall bend 180°; the ends having a length beyond the bend of not less than 6 inches and the value of the anchorage shall be taken as equal to 1000 pounds multiplied by the concave side of the bar in inches, multiplied by the diameter of the bend in inches.

Note.—Usually, when bars are anchored at the ends, the stress at the point of anchorage is much less than the working strength of the bar, the greater part of the load having been already relieved by adhesion, and a radius of bend of 3 inches will be sufficient, provided that ⅝ of the load is taken care of by adhesion.

In computing *Deflection* of reinforced concrete beams or slabs, the formula given in section D shall be used.

49. In computing reinforced concrete Footings, the maximum compression at the top of the footing due to the direct load from the columns combined with the compressive stress due to bending shall not exceed the allowable limits for concrete in compression due to loading. The footings must be deep enough to transmit the entire load from the columns through shear on the concrete without reliance upon the steel reinforcing of the footing for assistance in such resistance to shear. In reinforcing footings the reinforcing bars must be so spaced as to properly transmit the load carried by the column uniformly onto the foundation. All reinforcing bars in footings subjected to moisture must be protected by at least four inches of *rich* concrete.

50. In all cases where Combined Stresses occur, such as the bearing of heavy concentrated loads on the top of beams, combined with the compression in the beam due to bending, etc., the resultant combined stress must not exceed the maximum allowed stress.

51. In the case of the so-called Mushroom or Flat Plate System of construction or other systems which are not subject to rigid stress analysis the designs will be accepted only subject to tests upon the completed structure as hereinafter provided for.

52. A Range of Temperature from +20° to +90° Fahr. will be assumed for latitude 40° and this shall be increased for higher latitudes and decreased for lower latitudes. Stresses due to temperature will be combined with dead and live load stresses to obtain maximum unit stress.

53. The pressure of earth fill over the tops of culverts imbedded in earth embankments shall be assumed to be equal to the total weight of the material above the top of the culvert without any allowance for arching action.

54. The lateral pressure on the side walls of culverts embedded in earth embankments shall be assumed to be equal to 25% of the weight on the top.

55. Members subject to both axial (direct) and bending stresses shall be proportioned so that the combined stresses shall not exceed the allowed axial stress.

56. The coefficient of expansion of concrete due to temperature changes shall be assumed to be .000006 per degree Fahr.

The coefficient of contraction, or shrinkage, of concrete, set in air, shall be assumed at .002 divided by ratio of the aggregate to the cement.

Unit Stresses

1. The unit stresses given in this section apply only to concrete of the given mixtures proportioned as herein specified for these standard mixtures and possessing the strength specified therefor.

2. The bearing of masonry plates on No. 9 concrete shall not exceed 400 lbs., per sq. in.; on No. 6 concrete 500 lbs.; on No. 3 concrete 600 lbs. per sq. in.

3. The direct compressive stress in massive concrete shall not exceed 400 lbs. for No. 9 concrete or 500 lbs. for No. 6 concrete.

4. The compressive stress in reinforced concrete due to bending shall not exceed 600 lbs. per sq. in. for No. 9 concrete nor 750 lbs. per sq. in. for No. 6 concrete, when determined by the straight line formula.

(Note.—This unit stress of 750 lbs., per sq. in. determined by the straight line formula as used in these specifications is equivalent to 630 lbs., per sq. in., when determined by the parabolic formula which represents more correctly the actual conditions, but is not used herein because it is much more complicated than the straight line and the latter has been found to give results which are perfectly safe.)

5. The direct compression on plain concrete columns shall not exceed 400 lbs. per sq. in. and the length of such columns shall not exceed 12 times their least side.

6. The direct compression on reinforced concrete columns whose length does not exceed 15 times the diameter or least side, shall not exceed 500 lbs. per sq. in. when the reinforcing is equal to 1% of the concrete section, which is the minimum amount of reinforcing which shall be considered in a reinforced concrete column. All columns having less than this amount shall be assumed to be plain concrete columns.

In case the columns be reinforced by hooping, this unit stress may be increased to 600 lbs. per sq. in. provided that the amount of hooping be not less than 1% of the vertical section, and hoops be spaced not more than 6 inches apart.

For all cases, the fibre stress on the steel shall be taken not greater than 15 times that on the concrete and no direct allowance shall be made for the steel used as hooping.

In the case of hooped columns, the concrete area enclosed by the hoops only shall be considered as effective column area.

For percentages of hooping greater than 1%, the compression on the concrete core may be increased 100 lbs. per sq. in. for each 1% increase in area of hoops and spirals, provided that the former be welded and the latter continuous, and that the unit stress on concrete core does not exceed 1000 lbs. in any case. Also that the distance between hoops and spirals decrease 1 inch for each 1% of area.

For each additional 100 lbs. compression on concrete core, exceeding 600 lbs., the ratio of cement to aggregates must be increased 10%.

7. Longitudinal bars shall be securely tied together at intervals not exceeding one foot nor 12 times the diameter of the main bars.

Tie rods shall be not less than ¼ inch in diameter for all main longitudinal bars of 1 inch or greater in diameter, or ¼ the size of main bars for smaller sizes.

8. Effective means must be provided for splicing the longitudinal reinforcing bars in columns or if the bars be not spliced, but dependance be made upon the adhesion of the concrete to transmit the stress from one bar to another, then the concrete area must be of sufficient section at the point of splice to carry the entire load without assistance from the steel.

9. Butt joints if used for column rods must have pipe sleeves or other efficient means for keeping bars in line and the ends of the bars must be milled.

10. When the length of a reinforced concrete column exceeds 15 times its least side or diameter, the unit stresses in both steel and concrete shall be decreased by an amount equal to the length of the column, divided by 100 times its least side or diameter, in inches.

11. The longitudinal reinforcing bars in columns shall not exceed 10% of the concrete section or else structural steel shapes shall be used.

12. The above values for columns are based upon the use of a 1-2-4 (No. 6) rock concrete mixture.

Columns of leaner concrete must have these values reduced in proportion as the ultimate strength of the mixture used, is to that of 1-2-4 concrete.

13. The compressive stress on 1-2-4 natural cement concrete must not exceed 200 lbs. per sq. in.

14. The direct shearing stress on concrete shall not exceed 120 lbs. per sq. in. for No. 9 concrete nor 150 lbs. per sq. in. for No. 6 concrete.

15. The *Adhesive* stress of concrete to plain steel bars shall not exceed 60 lbs. per sq. in. for 1-2-4 (No. 6) stone concrete, nor 50 lbs. for 1-3-6 (No. 9) concrete. When *Deformed Bars* are used, these values may be doubled.

Note.—The length of anchorage required to develop the full strength of plain and round bars shall be taken at 60 times the diameter or side, for rods embedded in 1-2-4 concrete. This anchorage may be reduced 50% for deformed bars and may be reduced 50% for plain bars anchored at the ends by bending through 180 degrees.

16. The tensile stress on 1-2-4 (No. 6) concrete shall not exceed 50 lbs. per sq. in. This limit refers to the diagonal tension in the web caused by shearing stresses and is sometimes referred to as diagonal shear. It shall be assumed as equal to the unit shearing stress in all reinforced concrete beams. When the unit diagonal tensile stress exceeds 50 lbs. on 1-2-4 concrete, the strength of the concrete in tension shall be completely ignored and the web reinforced to take care of the entire diagonal tension.

17. For mixtures other than 1-2-4 the unit stresses shall be varied in the ratio of the ultimate strength of the mixture used in compression to the ultimate strength of 1-2-4 concrete which shall be assumed at 2,400 pounds per sq. in.

The diagonal tension in concrete beams shall never exceed 150 lbs. per sq. in. assuming the concrete to take all the stress, disregarding the web reinforcing.

18. The working stress of steel reinforcing bars in tension shall not exceeed for any kind of material, 16,000 lbs. per sq. in.

Note.—This limit of 16,000 lbs. is taken for all material because the concrete commences to crack in tension at the same unit stress in the reinforcing steel, regardless of the quality of the latter.

While no allowance is made in working stress for steel having a high elastic limit, or high carbon steel, such steel is often desirable because the factor of safety against the ultimate failure is made greater by its use.

19. The maximum allowable stress on *Steel in Compression* shall not exceed the maximum co-existing stress in the contiguous concrete multiplied by the ratio of the modulus of elasticity of the steel to that of the concrete.

20. Steel bars used to resist compression shall not be deformed, and shall be secured by stirrups or other lateral ties at intervals not greater than 12 times the diameter.

28. The maximum allowable loads on *Foundations* shall, unless otherwise indicated, be taken as follows:

On dry coarse gravel, well cemented, five tons (10,000 lbs.) per sq. ft.

On dry hard fine sand, four tons (8,000 lbs.) per sq. ft.

On dry hard clay, three tons (6,000 lbs.) per sq. ft.

On wet sand, two tons (4,000 lbs.) per sq. ft.

On wet clay, one ton (2,000 lbs.) per sq. ft.

The maximum allowable load on foundation material other than that given will be determined for each individual case by the Engineer in charge.

22. In the case of *Reinforced Steel Construction,* in which the steel frame, when not encased in concrete, is designed to carry a definite portion of the loads, the unit stresses in the steel frame, when carrying its portion of the load alone, must not exceed those allowed by the specifications of the American Bridge Co. or by Watson's Specifications for Steel Bridges for similar class of structure, and the unit stresses in the steel and concrete after completion shall not exceed those given herein for reinforced concrete construction.

23. The stresses in timber framing for forms and centers must not exceed the unit stresses allowed by Watson's Specifications for timber construction.

24. For other mixtures than specified herein, the unit stresses shall be in proportion to the strength of the material as shall be shown by tests.

The unit stresses given in this section apply only to proportions and mixture as specified in Section F and to materials as specified in Section E.

Formulae

In computing unit stresses, moments of resistances, etc., the following formulae shall be used.

NOTATION

The units are always lbs. and inches unless otherwise stated.

d_1 = Total depth of beam.

d_2 = Distance from compressive surface to center of steel reinforcing.

d_3 = jd_2 = Distance from centroid of compressive forces to center of steel.

j = Ratio of distance between centroid of compressive forces and center of steel to distance of center of steel below outside compressive surface of concrete.

x = Ratio of depth of neutral axis to depth of steel in tension.

xd_2 = Distance from compressive surface to neutral axis of beam.

h = Ratio of depth of steel in compression to depth of steel in tension.

b_1 = Width of simple beam or width of stem of **T** beam.

b_2 = Width of flange of **T** beam.

t = Thickness of flange of **T** beam.

o = Periphery of reinforcing bars at any section.

a_1 = Area of steel tension bars at any cross-section.

a_2 = Area of web reinforcing bars at any longitudinal section equal to d_3 in length.

a_3 = Area of steel compression bars at any cross-section.

R = Ratio of cross-section of steel in tension to cross-section of beam above the center of gravity of the steel in tension.

R_1 = Ratio of cross-section of steel in compression to cross-section of beam above the center of gravity of the steel in tension.

s = Spacing of stirrups at any section.

M = Bending moment in foot pounds.

m = Bending moment at any section from exterior forces, in inch lbs.
= Moment of resistance at any section, in inch lbs.

V = Vertical shear at any section.

f = Maximum fibre stress in steel in tension.

f_c = Maximum fibre stress in steel in compression.

u = Maximum unit stress in concrete in compression.

u_t = Maximum unit stress in concrete in tension.

v_s = Maximum unit stress in concrete in shear.

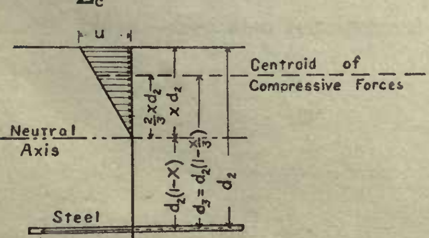
u_a = Maximum unit stress in adhesion of concrete to steel.

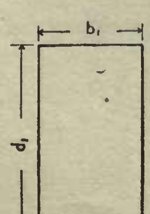
E_s = Modulus of elasticity of steel.

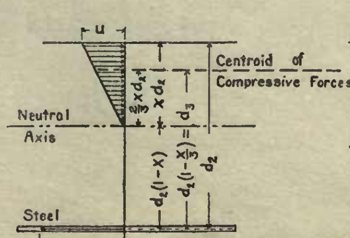
E_c = Modulus of elasticity of concrete in compression.

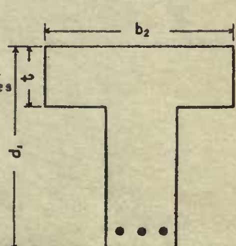
E_t = Modulus of elasticity of concrete in tension.

$$\frac{E_s}{E_c} = n$$









(1) $x = - nR + \sqrt{2nR + (nR)^2}$
(2) $d_3 = d_2 (1 - \frac{x}{3}) = jd_2$
(3) $a_1 = m \div jd_2 f = m \div d_3 f$
(4) $u = Cm \div bd_2{}^2$ where $C = \frac{2}{x(1-\frac{x}{3})}$

NOTE.—Values of C will be found in the following table. These values will give a value of u_1 based upon the use of the straight line formula. The actual compression on concrete will be only 85% of this and this reduction should be made when meeting requirements of City Building Ordinances or other regulations, which are based upon the use of the parabolic method of analysis.

(5) $v = V \div jb_1d_2 = V \div d_3b_1$
(6) $a_2 = vb_1d_3 \div f = V \div f$

NOTE.—This formula to be used only when value of V_o exceeds the allowable unit web tension on concrete, and f can be used only when the web member is attached to the main reinforcing bars in such a way as to be able to transmit its full value in tensile stress to the latter by direct tension. When the attachment is such as to induce shearing stresses in the web reinforcing member, this stress must be reduced 25%.

See other requirements under assumption for computing and designing.

The expression b_1v is called the *Intensity of the shear* at any section.

(7) $u_a = fa_1 \div oy$
where y = distance to end of bar from point considered.

The length of reinforcing bars required in a simple beam uniformly loaded may be determined as follows:

(8) $x_n = l\frac{\sqrt{a_1 + a_2 + \ldots + a_n}}{\sqrt{A}}$

where x_n = length of nth rod in the order of length, counting the shortest as number one; l = span length.

A = total area of steel at center; and a_1, a_2, etc., = area of each rod up to the nth rod.

For unsymmetrical loading the maximum moments and shears must be determined at various sections and the lengths of bars obtained therefrom preferably by plotting the moment and shear diagrams.

(9) $D = \frac{F(fl^2)}{Qd_2(1-X)} \div 1{,}000{,}000$

When D = deflection at middle of span in inches

F = factor = one inch for 16,000 lbs. steel fibre stress, decreasing 0.04 for each decrease of 1,000 lbs., and increasing 0.02 for each increment of 1,000 lbs.

Q = a constant = 288 for simple beams uniformly loaded, = 384 for partially constrained beams = 480 for continuous or constrained beams.

TEE BEAMS

By the use of the "Table for Designing T Beams," T beams may be designed in exactly the same manner as simple rectangular beams, by considering the width "b_2" of the T beam to correspond to the width "b_1" of the rectangular beam, and the area of concrete above the steel to be equal to "$d_2 b_2$."

When the thickness "t" of the flange is less than the distance from the compressive surface of the slab to the neutral axis, the unit stresses on concrete in compression are increased, and therefore in designing T beams as if they were simple rectangular beams, a corresponding reduction in the allowable unit stresses on concrete in compression, and a corresponding reduction in the percentage of reinforcement must be made.

The following table gives this reduction in allowable stresses on concrete in terms of the ratio of the thickness of the flange "t" to the depth "d_2" and the ratio of the width "b_2" of the T beam to the width "b_1" of the stem.

The corresponding allowable percentage of steel reinforcement may be obtained from the "Table of Constants and Concrete Unit Stresses for Different Percentages of Steel."

In the investigation of T beams, the actual compressive stress may be obtained by computing the compressive stress which would occur in a simple beam of width "b_2" and multiplying this by the ratio of 750 divided by the unit stress given in the Table for Designing T Beams for the given value of "$\frac{t}{d_2}$" and "$\frac{b_2}{b_1}$"

Compressive Reinforcement

When it is found necessary to provide reinforcement in the compression flange, the resisting moment of the beam, assuming the maximum allowable unit stress in the concrete of the compression flange and the corresponding percentage of steel in the tension flange shall be deducted from the total external bending moment, and the remaining moment (m_2) be provided for by introducing additional reinforcement in both flanges at the specified unit stresses in tension and compression.

$m_2 = m - m_1$

if d_4 = distance between reinforcement in flanges

additional steel in tension flange $= m_2 \div (d_4 f)$

" " " compression flange $= m_2 \div (15\, d_4 u)$

Column formula for unit stress (u^1) in all columns whose length (l) exceeds 15 times the least side or diameter (d), and is less than 30 times the least side or diameter (d):

$u^1 = u\,(1 - \frac{l}{100d})$

NOTE.—See also requirement for anchorage of compression bars.

TABLE FOR DESIGNING T BEAMS,

FOR HIGH STEEL, $f_s = 20000$						
$t \div d_2$	$b_2 \div b_1$					
	1.5	2.0	2.5	3.0	3.5	4.0
.10	669	629	603	586	574	564
.15	700	674	660	650	642	636
.20	723	709	700	694	690	687
.25	737	732	728	725	723	722
.30	745	743	742	742	741	741
.35	750	750	750	750	749	749

FOR MEDIUM STEEL $f_s = 16000$						
$t \div d_2$	$b_2 \div b_1$					
	1.5	2.0	2.5	3.0	3.5	4.0
.10	660	611	584	565	550	538
.15	690	657	639	625	617	610
.20	712	692	681	673	668	664
.25	728	718	712	708	705	702
.30	740	735	732	730	728	727
.35	746	745	744	744	743	743

VALUES OF μ_c TO BE USED IN DESIGNING T BEAMS AS SIMPLE RECTANGULAR BEAMS ARE GIVEN IN BODY OF TABLE

TABLE OF CONSTANTS AND CONCRETE UNIT STRESSES FOR VARIOUS PERCENTAGES OF STEEL

PERCENTAGE OF REINFORCEMENT	$\frac{E_s}{E_c}$	WORKING STRENGTH OF STEEL	WORKING STRENGTH OF CONCRETE	j	x	C
0.20	15	20000	370	.928	.217	9.93
0.30	15	20000	463	.914	.258	8.48
0.40	15	20000	550	.903	.292	7.58
0.45	15	20000	588	.898	.306	7.28
0.50	15	20000	627	.893	.320	7.00
0.55	15	20000	663	.889	.332	6.78
0.60	15	20000	699	.885	.344	6.57
0.65	15	20000	734	.882	.355	6.39
0.676	15	20000	750	.880	.360	6.31
0.676	15	20000	633	by parabolic theory.		
0.40	15	16000	440	.903	.292	7.59
0.50	15	16000	500	.893	.320	7.00
0.60	15	16000	558	.885	.344	6.57
0.65	15	16000	587	.882	.355	6.39
0.70	15	16000	613	.878	.365	6.24
0.75	15	16000	640	.875	.375	6.10
0.80	15	16000	666	.872	.384	5.97
0.87	15	16000	702	.868	.397	5.80
0.90	15	16000	717	.866	.402	5.75
0.95	15	16000	741	.863	.410	5.65
0.97	15	16000	750	.862	.413	5.62
0.97	15	16000	629	by parabolic theory.		

Unit stresses in concrete 15% less when computed by "Parabolic" instead of "Straight Line" theory.

Quality of Materials for Concrete Work.

1. All *cement* shall be, unless otherwise specified, American Portland cement of a well known and tried brand. If so specified on the drawings, Pozzulan cement (sometimes called Slag cement) may be used for concrete work underground, such as footings, etc., where it is not subjected to the action of the atmosphere, and for concrete work constantly immersed in water. All cement shall be purchased subject to the standard tests of the American Society for testing materials as adopted November 14, 1904, and as may be subsequently amended, and these tests shall be made in strict accordance with the methods prescribed by the Committee on Uniform tests of the American Society of Civil Engineers. Tests shall be made from at least each car-load of cement and no cement shall be used on the job until such tests shall have been made. Cement must be ordered sufficiently in advance of its use to allow at least 28 days for testing.

2. The requirements for *Portland cement* are, briefly, as follows:

The specific gravity, thoroughly dried at 100° centigrade, shall be not less than 3.10.

For fineness it shall leave by weight a residue of not more than 8 per cent on the No. 100 and not more than 25 per cent on the No. 200 sieve.

For time of setting, it shall develop the initial set in not less than 30 minutes but must develop the hard set in not less than one hour or more than 10 hours.

The minimum requirements for tensile strength of neat cement shall be as follows:

Age—24 hours in moist air, 175 lbs.
Age—7 days (one day in moist air, 6 days in water), 500 lbs.
Age—28 days (one day in moist air, 27 days in water), 600 lbs.

For tensile strength of briquettes composed of one part cement to three parts sand, the requirements shall be as follows:

Age—7 days (one day in moist air, 6 days in water), 175 lbs.
Age—28 days (one day in moist air, 27 days in water), 250 lbs.

For constancy of volume three parts of neat cement about 3" in diameter and about ½" at the center and tapering to a thin edge shall be made, one of which shall be kept in moist air for a period of 24 hours and then in air at normal temperature for 28 days. Another shall be kept in moist air for 24 hours and then kept in water maintained as near 70° Fahr. as practical for 28 days. The third shall be exposed in an atmosphere of steam above boiling water in a loosely closed vessel for five hours. These parts shall remain firm and hard under the above tests and shall show no signs of distortion, checking, cracking or disintegration.

Portland cement shall contain not more than 1.75 per cent of anhydrous sulphuric acid nor more than 4 per cent of magnesia (Mgo.).

3. *Pozzulan cement,* if used, will be understood to mean cement made directly from blast furnace slag and lime without calcination subsequent to the mixing. It shall be used only under water or other places where thoroughly protected from the atmosphere. It shall weigh not less than 330 lbs. per barrel and it shall meet the fineness, soundness and setting tests as prescribed for true Portland cement and shall have a specific gravity of not less than 2.7 and shall develop a tensile strength not less than 75 per cent of that specified for Portland cement.

4. True Portland cement made from blast furnace slag will be classed with other Portland cements.

5. *Stone* for massive concrete work shall be crushed, hard limestone, granite, trap, or other suitable hard stone in graded sizes of from ¼ to 3" where it is practical to use sizes as large as this.

Stone for reinforced concrete work shall be of similar material but of smaller size. For ordinary work, sizes shall be from ¼ to 1". For small reinforced concrete sections the maximum size shall not exceed ¾".

All stone shall have a cubical fracture and shall be of material that is not subject to disintegration, due to atmospheric or other influences to which the concrete will be subject.

6. *Sand* shall be clean, hard, and free from more than 5 per cent of loose earth or loam or other foreign matter and shall be entirely free from any impurities adhering to the surface of the grains of sand.

Unless otherwise specified, 60 or 70% of the particles shall be retained on a number 40 sieve.

Sand must consist of definite grains and care must be taken that the grains be not too fine. A graded sand is to be preferred.

7. *Gravel* for concrete work shall be clean graded gravel in sizes specified for stone. No soft stone, shale or other materials subject to disintegration will be allowed. When gravel is not well graded or not uniform, the Engineer will determine the proportions for each grade brought upon the work, so as to give results equivalent to those of the specified mix, or may require all gravel to be screened, at his discretion. The Engineer may at his discretion require gravel to be washed.

8. *Slag* for concrete work shall be crushed slag in sizes similar to those specified for crushed stone and shall be nearly free from sulphur or other injurious agents and must be hard and not spongy.

9. All stone, gravel or slag shall be screened, unless otherwise distinctly arranged with the Engineer and shall be subject to the Engineer's acceptance.

10. Stone *screenings* will not be used except by express permission of the Engineer in charge, who will determine the amount of sand to be added to the screenings for each particular case or if found necessary to screen the material, he will decide what part of the material shall be screened out.

11. *Water* used in concrete mixing must be reasonably clear and free from organic substances. Roily or brackish water must not be used. Sea water will not be allowed.

12. *Steel* for reinforced concrete construction shall be one of the following grades:

(A) *Medium Open-Hearth Steel* for reinforced concrete shall be manufactured in accordance with the Manufacturer's Standard Specifications for this grade of material, as revised February 3, 1903, and subject to subsequent revisions of the same. It shall be purchased subject to the usual tests as specified in the standard specifications above mentioned. It shall have an ultimate strength of from 60 to 70 thousand pounds per square inch; an elastic limit of not less than one-half the ultimate strength. It shall be capable of being bent 180 to a diameter equal to the piece tested without fracture on the outside of the bent portion. It shall contain not over .06% of phosphorus and not over .05% of sulphur.

(B) *High Carbon Steel* shall contain not over .08% of phosphorus, .08% of sulphur, and not more than .08% nor less than .04% of manganese. The ultimate tensile strength shall not be less than 90,000 lbs. per sq. inch and the elastic limit not less than ½ the ultimate strength. The elongation at 8″ shall be not less than 10%.

For materials less than 5/16″ and more than ¾″ in thickness the following modifications shall be made in the requirements for elongation.

(a) For each increase of ⅛″ in thickness above ¾″ a deduction of 1% shall be made from the specified elongation.

(b) For material from ¼″ to, but not including 5/16″ thick, the elongation shall be 8%.

For material from 3/16″ to, but not including ¼″ thick, the elongation shall be 7%.

For material from ⅛″ to, but not including 3/16″ thick, the elongation shall be 6%.

For materials less than ⅛″ thick, the elongation shall be 5%.

Bending Test. Test specimens for bending shall be bent cold around a diameter equal to their thickness to the following angles without fracture on the outside of the bent portion.

For specimens 1 inch thick, 80°. For specimens ¾″ thick, 90°.

For specimens ½″ thick, 110°. For specimens ¼″ thick, 130°.

For specimens 3/16″ thick, 140°. For specimens ⅛″ thick, 160°.

(c) *Bessemer High Carbon Steel* shall include steel bars made either from new stock by the Bessemer process or by the re-rolling of old rails. The amount of phosphorus shall not exceed 0.10%, sulphur, 0.08%; manganese not more than .08% nor less than 0.04%.

The ultimate tensile strength shall be not less than 90,000 lbs. per sq. inch and the elastic limit (yield point) not less than one-half the ultimate strength.

The elongation in 8″ shall be not less than 10 per cent.

For materials less than 5/16″ and more than ¾″ the thickness the following modifications shall be made in the requirements for elongation.

(a) For each increase of ⅛″ in thickness above ¾″ a deduction of 1% shall be made from the specified elongation.

(b) For material from ¼″ to, but not including 5/16″ thick, the elongation shall be 8%.

For material from 3/16″ to, but not including ¼″ thick, the elongation shall be 7%.

For material from ⅛″ to, but not including 3/16″ thick, the elongation shall be 6%.

For materials less than ⅛″ thick, the elongation shall be 5%.

Bending Test. Test Specimens for bending shall be bent cold around a diameter equal to their thickness to the following angles without fracture on the outside of the bent portion.

For specimens 1″ thick, 80°. For specimens ¾″ thick, 90°.

For specimens ½″ thick, 110°. For specimens ¼″ thick, 130°.

For specimens 3/16″ thick, 140°. For specimens ⅛″ thick, 160°.

(d) *Cold twisted square bars* of medium steel shall be made from medium steel which will meet all requirements before twisting, as given under (a).

The bars shall be twisted cold and after twisting shall have an ultimate strength of not less than 70,000 lbs., an elastic limit of not less than 50,000 lbs. per sq. inch. Bars after twisting must bend 180° around their own diameter. Bars which show any defect whatever during cold twisting process shall be rejected.

(e) Cold Twisted Square Bars of Bessemer Steel will be used only by special permission and must meet all requirements given herein for open hearth steel except that the amount of phosphorus shall not exceed 0.10%. The number of turns for cold twisted bars per foot shall not exceed 3 for ½″, 2 for ⅝″, 1½ for ¾″, 1¼ for ⅞″, 1 for 1″, ⅞ for 1⅛″, ¾ for 1¼″, ⅝ for 1⅜ and ½ for 1½″.

Note.—Deformed bars shall not be used for *column reinforcing.*

13. Wherever practicable, the standard test specimen used and described in the Manufacturers Standard Specifications for medium steel shall be used in making tests.

The bending tests will be preferably made by slowly applied pressure.

Check analysis for chemical composition may be made from drillings.

14. Medium steel which has been subjected to twisting or other treatment such as to raise its ultimate strength and elastic limit to that given for high steel may be considered as equal to high steel and may be bent and may be used in railroad and electric railway structures if it meets the bending test prescribed for high carbon steel.

15. Unless otherwise shown on the drawings all reinforcing steel shall be Plain Round Bars, and in case deformed bars are specified they shall be of the section as specified on the drawings, or in case the drawings do not state what form of deformation is to be used, the Contractor shall furnish bars which will be satisfactory to the Engineer.

16. Deformed Bars will be used in all cases where it is not possible to develop the strength of the plain bar by adhesion and will be preferred in all railroad and electric railway structures, and other structures subject to considerable vibration.

17. The quality and shape of reinforcing steel to be used must be as shown on the drawings.

18. Chain or cable reinforcing shall not be used unless it is of a type that shall have been shown by tests satisfactory to the Engineer not to stretch more than plain bars of same net cross section under the same load.

(c) *Material—High Carbon Steel* shall include steel bars made either from new stock by the Bessemer process or by the re-rolling of old rails. The amount of phosphorus shall not exceed 0.10%, sulphur .05%; manganese not more than .08% nor less than 0.60%.

The ultimate tensile strength shall be not less than 80,000 lbs. per sq. inch and the elastic limit (yield point) not less than one-half the ultimate strength.

The elongation in 8" shall be not less than 10 per cent.

For materials less than 7/16" and more than 3/4" the thickness the following modifications shall be made in the requirements for elongation.

(a) For each increase of 1/8" in thickness above 3/4" a deduction of 1% shall be made from the specified elongation.

(b) For material from 7/16" to, but not including 5/16" thick, the elongation shall be 8%.

For material from 5/16" to, but not including 1/4" thick, the elongation shall be 7%.

For material from 1/4" to, but not including 3/16" thick, the elongation shall be 6%.

For materials less than 3/16" thick, the elongation shall be 5%.

Bending Test. Test Specimens for bending shall be bent cold around a diameter equal to their thickness to the following angles without fracture on the outside of the bent portion.

For specimens 1" thick, 80°. For specimens 3/4" thick, 90°.

For specimens 1/2" thick, 120°. For specimens 3/8" thick, 150°.

For specimens 5/16" thick, 180°. For specimens 1/4" thick, 180°.

(d) *Cold twisted square bars* of medium steel shall be made from medium steel which will meet all requirements before twisting, as given under (a).

The bars shall be twisted cold and after twisting shall have an ultimate strength of not less than 70,000 lbs., an elastic limit of not less than 50,000 lbs. per sq. inch. Bars after twisting must bend 180° around their own diameter. Bars which show any defect whatever during cold twisting process shall be rejected.

(e) Cold Twisted Square Bars of Bessemer Steel will be used only by special permission and must meet all requirements given herein for open hearth steel except that the amount of phosphorus shall not exceed 0.10%. The number of turns for cold twisted bars per foot shall not exceed 3 for 1/4", 2 for 3/8", 1¾ for 1/2", 1½ for 5/8", 1 for 3/4", 7/8 for 1", 3/4 for 1⅛", 5/8 for 1¼ and 1/2 for 1½".

Note.—Deformed bars shall not be used for column reinforcing.

14. Wherever practicable, the standard test specimens used and described in the Manufacturers Standard Specifications for medium steel shall be used in making tests.

The bending tests will be preferably made by slowly applied pressure.

Check analysis for chemical composition may be made from drillings.

(f) Medium steel which has been subjected to twisting or other treatment such as to raise its ultimate strength and elastic limit to that given for high steel may be considered as equal to high steel and may be bent and may be used in railroad and electric railway structures if it meets the bending test prescribed for high carbon steel.

15. Unless otherwise shown on the drawings all reinforcing steel shall be Plain Round Bars, and in case deformed bars are specified they shall be of the section as specified on the drawings, or in case the drawings do not state what form of deformation is to be used, the Contractor shall furnish bars which will be satisfactory to the Engineer.

16. Deformed Bars will be used in all cases where it is not possible to develop the strength of the plain bar by adhesion and will be preferred in all railroad and electric railway structures, and other structures subject to considerable vibration.

17. The quality and shape of reinforcing steel to be used must be as shown on the drawings.

18. Chain or cable reinforcing shall not be used unless it is of a type that shall have been shown by tests satisfactory to the Engineer not to stretch more than plain bars of same net cross section under the same load.

Proportioning, Mixing and Placing Concrete.

1. All concrete proportions specified herein will be based upon the assumption that one barrel of Portland Cement is equivalent to 3.8 cubic ft. and all proportioning must be done by means of a carefully gauged wheelbarrow or other apparatus of capacity which will be determined by the Engineer.

2. Quantities of materials required for one cubic yard by specified proportions.

All volumes as given herein shall be measured loose.

Mix. No.	Proportion.	Cement in barrels.	Sand cu. yds.	Stone, Slag or Gravel, cu. yds.
4½	1-1½-3	2.00	0.42	0.84
5	1-2-3	1.81	0.51	0.76
6	1-2-4	1.57	0.44	0.88
7½	1-2½-5	1.30	0.46	0.92
9	1-3-6	1.11	0.47	0.94
11½	1-3-6x¼ rubble	0.83	0.37	0.72
10½	1-3½-7	0.89	0.47	0.95
13	1-3½-7x¼ rubble	0.68	0.35	0.71

3. The required minimum compressive strength of specified proportions shall be as follows:

Mix. No.	Proportion.	7 da.	28 da.	3 mo.	6 mo.
4½	1:1½:3	1500	2575	3130	4000
6	1:2:4	1400	2400	2900	3700
7½	1:2½:5	1300	2225	2670	3400
9	1:3:6	1200	2050	2440	3100
11½	1:3:6x¼ rubble	"	"	"	"
10½	1:3½:7	1100	1875	2210	2800
13	1:3½-7x¼ rubble	"	"	"	"

The above values are based upon Thacher's formulas for strength of concrete.

4. The unit stresses given in Section C and formula given in Section D apply to concrete which shall show strengths equal to those given above for stone or gravel concrete. For mixtures which show a less strength the unit stresses shall be correspondingly reduced.

5. In determining the compressive strength the latter may be assumed at nine (9) times the tensile strength of Standard briquettes having the same proportion of cement to sand as used in the concrete.

6. All *mixing* shall be by machinery, except such hand mixing as may be allowed by special arrangement with the Engineer.

7. If concrete is mixed by hand the sand and cement shall be spread upon the mixing board in thin layers and turned with spades until the mixture is of uniform color. Stone and water shall then be added and the mix shall then be turned at least three times, not counting the shoveling off the board.

8. Preference will be given to revolving batch machines which automatically measure the ingredients of the mix. Mixing must be very carefully and thoroughly done. Enough water must be used to make the mass plastic enough to run freely, in other words a wet mix will be required for all reinforced concrete work.

9. For massive concrete work only enough water will be used to make the concrete plastic, not so wet but that it may be churned with a light tamper sufficient to quake the mass.

10. The concrete shall be placed in position immediately after mixing and before the initial set shall have taken place.

11. Unless specifically required, reinforced concrete will not be rammed, but when ramming is required all concrete whether massive or reinforced must be thoroughly tamped. This tamping must be carried on continuously during the process of placing the concrete and should be done by means of blades manufactured especially for this purpose.

Special care should be taken in tamping concrete next to the forms in order to insure that the mortar is flushed thoroughly against the latter.

12. No *retempering* of concrete which has been allowed to stand until the initial set has taken place will be allowed unless by special permission of the Engineer, who may, at his discretion, require additional cement to be used in retempering.

13. The mixing and placing of concrete will be as far as practicable a continuous operation, and when it is necessary to make a joint in monolithic concrete, it shall preferably be made in the middle of a panel at right angles to the beams and by means of a stop board placed in a vertical position and containing a key on the side next the concrete first placed. When these stop boards are removed, the exposed surfaces of concrete shall be wet and carefully dusted with neat cement or painted with mortar before continuing the next block.

14. When it is necessary to *bond* new concrete to concrete partially or wholly set, the Engineer may require that the surfaces of the old concrete be roughened either by picking or by washing with acid, thoroughly rinsing same off and applying a thin coat of rich cement mortar, 1 to 1, or a bonding preparation may be used by permission of the Engineer. It will always be required in joining new concrete to old that has partially set, that that part of the old concrete next to the forms shall be removed for a depth of at least 1 inch and a distance back from the face of the concrete of at least 2″ in order to avoid the appearance of the joint.

It will also always be necessary to remove all *laitance* from the surface of concrete which has partially set before attempting to bond new concrete thereto.

15. Concrete must be kept wet for one week after depositing and in dry hot weather must in addition be kept covered from exposure to the sun during this time, or must be constantly sprinkled during the day by a workman especially detailed for this work.

16. Natural cement concrete will only be used, if at all, in foundations underground and for the center or core of massive structures, and when so used, mix No. 6 will be used, unless otherwise specified.

17. When it is necessary to place concrete under water, the structure should be encased with a cofferdam or other means taken to procure quiet water and then the material should preferably be deposited from a bucket provided with a bottom dump or a tremie may be used. Care must be taken to keep the deposited concrete as nearly horizontal as possible when depositing under water.

18. When the concrete must be deposited in running water it will be done by placing the concrete in bags and depositing the bags in place, or by other means equally satisfactory to the Engineer.

19. Unit stresses on concrete deposited as per paragraph 17 must be decreased 33 1/3 per cent and when deposited as per succeeding paragraph, 50 per cent.

20. *Rubble Concrete*—In heavy foundation work or other work requiring large masses of concrete, the Contractor may use not to exceed 25 per cent of one man stones to imbed in the concrete when so indicated on the drawings. Such stones must be sound, clean and wet before placing, and shall not be placed nearer than one foot from the surface of the concrete and not less than six (6) inches apart. They must be laid with their largest face at right angles to the line of principal stress.

21. In placing concrete it shall not be dropped from a greater height than 6 feet. When it is required to place concrete from a greater height than 6 feet, it shall be placed by means of chutes or other devices satisfactory to the Engineer in charge.

22. If other materials than carefully screened, broken stone, slag or cinders and sand as herein described be used, the proportions shall be subject to such changes as shall be found to give equivalent results in strength and density to the results obtained by use of the specified proportions and materials.

23. It is understood that these proportions and all other proportions given in these specifications are approximate only, and subject to such changes as may be found necessary in order to obtain properly proportioned mixtures after the Engineer shall have caused to have made careful analyses of the materials proposed to be used by the Contractor. Such adjustment of proportions will not be made, however, for any other purpose than that of properly filling the voids in the sand and stone.

24. In case such adjustment of the proportions entails a larger proportion of cement to aggregates than that specified, the Contractor will be allowed the actual cost, delivered at the mixer, of such additional cement, the amount to be determined by using the amount as given in the preceding table as a basis. In case a less amount of cement be required, a corresponding amount shall be deducted from the contract price.

25. In any mixture, the matrix (cement and sand mortar) shall exceed by 20% the voids in the aggregate (broken stone, gravel, etc.).

19. Unit stresses on concrete deposited as per paragraph 17 must be decreased 33 1/3 per cent and when deposited as per succeeding paragraph, 50 per cent.

20. *Rubble Concrete*—In heavy foundation work or other work requiring large masses of concrete, the Contractor may use not to exceed 20 per cent of one man stones to mixed in the concrete when so indicated on the drawings. Such stones must be sound, clean and wet before placing, and shall not be placed nearer than one foot from the surface of the concrete and not less than six (6) inches apart. They must be laid with their largest face at right angles to the line of principal stress.

21. In placing concrete it shall not be dropped from a greater height than 6 feet. When it is required to place concrete from a greater height than 6 feet, it shall be placed by means of chutes or other devices satisfactory to the Engineer in charge.

22. If other materials than carefully screened, broken stone, slag or cinders and sand as herein described be used, the proportions shall be subject to such changes as shall be found to give equivalent results in strength and density to the results obtained by use of the specified proportions and materials.

23. It is understood that these proportions and all other proportions given in these specifications are approximate only, and subject to such changes as may be found necessary in order to obtain properly proportioned mixtures after the Engineer shall have caused to have made careful analyses of the materials proposed to be used by the Contractor. Such adjustments of proportions will not be made, however, for any other purpose than that of properly filling the voids in the sand and stone.

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25. In any mixture the matrix (cement and sand mortar) shall exceed by 20% the voids in the aggregates (broken stone, gravel, etc.)

Requirements for Placing Reinforcing Steel

1. All steel for reinforcing shall be placed with great care, all abrupt bends must be avoided, except where one steel member is bent around another. Vertical Stirrups shall always pass under the main tension bars, or be rigidly attached thereto.

2. Steel reinforcing shall be secured against displacement during the pouring of the concrete, and shall be subject to a rigid inspection immediately prior to placing concrete.

3. The minimum distance from the surfaces of the concrete to the steel shall be two inches for columns, 1½ inches for girders and beams, 1 inch for slabs six inches and more in thickness and ¾ inch for slabs under six inches thick.

4. Main bars in slabs shall be spaced a distance apart not to exceed two times the thickness of the slab, and preferably not less than ¾ the slab thickness, and cross bars shall always be used at right angles to the main carrying bars. Cross bars shall not be less than ¼ inch diameter and spaced a distance apart not to exceed twice the specified maximum distance for main carrying bars.

5. The clear distance between reinforcing bars shall never be less than twice the maximum diameter of stone or bar used.

6. In the case of columns containing longitudinal reinforcing bars proper provision must be made for splicing such bars without any reliance upon the concrete for transmitting stress from one bar to another, unless the concrete section be sufficiently large at the point of splice to transmit such stress without overstraining the concrete. At the base of the column proper provision must be made for transmitting the load carried by the reinforcing bars.

7. Column bars 1 inch in diameter and over must be tied together by horizontal hoops not less than ¼ inch diameter and not farther apart than 12 inches. The distance between spirals or hoops in hooped columns shall not exceed four inches. For column bars less than 1 inch diameter the tie bars may be ¼ of the diameter of the column bars.

8. Wherever Bolts are to be embedded in the concrete, these bolts will be furnished by the Owner and placed in position by the Contractor.

9. The Contractor for Concrete work must place all anchor-bolts for columns, beams, etc., and must place all anchors and ties for all attachments to the concrete work, such as terra cotta or cast concrete trimmings and facings, brick facings, etc.

10. Wherever Pipes, Wires, Conduits, or other fixtures not otherwise provided for herein, are to be encased in the concrete work, they shall be furnished and placed under another contract, unless otherwise provided for on the plans or in the contract.

11. All metal must be free from scale, grease, paint, dirt or injurious rust before placing in the concrete.

Forms and Centers.

1. All forms for moulded concrete work will be constructed of sufficient strength to obtain the necessary rigidity to prevent any motion of the forms while concrete is being placed and shall be strong enough to carry any load which may come upon the concrete within 30 days from the date of placing the concrete.

2. Forms shall in general be composed of tongue and grooved sheeting, if ⅞″ sheeting be used, or carefully matched if heavier sheeting be used.

They shall be as nearly as possible water-tight and shall be surfaced on the side next the concrete for all surfaces which will be exposed in the finished work.

3. Forms shall be constructed by experienced and capable workmen only, and shall be true to line and grade and of first class workmanship throughout.

4. The forms for all exposed surfaces of concrete shall be smooth and the boards shall be carefully matched.

5. Forms which are used more than once shall be carefully cleaned off after each usage.

6. Great care must be taken to clean all saw dust, dirt or debris from forms just before placing concrete, and whenever necessary forms shall be cleaned out by steam jet or equally effective means.

All forms shall be so constructed as to be readily cleaned.

7. In general forms shall not be removed from concrete in less than 14 days in summer and 28 days in winter, except in the case of vertical surfaces, etc., which do not carry loads, the forms for which may be removed in from 3 to 6 days.

8. Forms shall always be removed from columns before removing shores from beneath beams and girders, in order to determine the condition of the column concrete. The supports for any concrete member in which the dead load exceeds the live load shall not be removed in less than twice the limits of time given above.

9. Centers shall not be struck from under arches in less than 28 days except in the case of arch culverts of less than 30 ft. span.

10. But no forms whatever shall be removed at any time without first notifying the Engineer in charge, who shall ascertain if the concrete be set sufficiently hard and so notify the Contractor. But such notification shall not be considered to relieve the Contractor of responsibility for the construction and for the removal of such forms.

11. Wherever practicable, edges of beams, girders and columns shall be chamfered and sides of beams and girders shall be splayed slightly in order that forms may be more readily removed.

12. All forms shall be designed so that they may be removed with as little damage as possible to the concrete or to the forms.

13. All projecting wires and bolts or other devices that are used for holding forms and that pass through the concrete shall be cut off at least one inch beneath the finished surface and the ends covered with cement mortar of the same mix as used in the body of the work.

14. In proportioning forms and centering, concrete shall be treated as a liquid of its full weight for vertical loads and one-half its weight for horizontal pressures.

15. The unit stresses used in proportioning forms shall not exceed the safe stresses allowed by Watson's specifications for timber construction.

16. In constructing timber centers for arches of more than 30 ft. span no reliance shall be placed upon spiking, but all main members must be bolted together at joints.

17. Wedges shall have a slope of 1 to 10.

18. In constructing timber centers for arches, an allowance for settlement shall be made equal to ¾″ for each 30 ft. vertical height.

19. Forms for beams and girders shall be cambered ¼″ for each 10 ft. span.

Surface Finish.

1. If no surface finish be called for, the surface of the concrete after removal of the forms will be gone over and all cavities, etc., filled with dry mortar of the same proportions as used in the original work, the mortar being forced into the cavities by pressure.

2. If the *Rubbed finish* be specified, as soon as the forms are removed the concrete surfaces shall be gone over with a piece of sand stone or No. 16 carborundum about the size of a brick which shall be used to grind down the surface of the concrete sufficiently to remove all impressions of the timber or other irregularities.

This sand stone shall be dipped in a cement wash composed of one part cement to two parts of fine sand, or preferably this wash may be applied with a brush and the concrete immediately ground down with the sand stone.

3. If a *Washed finish* be specified it shall be obtained by removing the forms within 8 or 10 hours after the concrete has been deposited, in warm weather, and washing out the cement film. In doing this the supports for arches and floors of any part of the work where the concrete is subject to stresses shall not be removed but only the sheeting of the exposed surfaces which are to be treated. If the cement has set so that it cannot be washed out with water, then a weak solution of hydrochloric or muriatic acid shall be used, the surface being thoroughly rinsed off afterwards.

4. If a *Dressed finish* be specified for moulded concrete, it shall be obtained by dressing with a sharp bush hammer and washing with muriatic acid diluted about one-half and carefully rinsed off. This can be done after the concrete has thoroughly set.

5. If a *Tooled surface* be specified the work shall preferably be done with pneumatic hammers or such other tools as are ordinarily used for similarly dressing stone surfaces.

6. Unless called for on the drawings there will be no *Mortar Facing* used in this work, but great care must be taken to insure the flushing of the cement against the forms. This shall be done by careful spading and puddling of the plastic concrete, for which special tools shall be provided as required.

7. In case a *Mortar Face* is called for, it shall be mixed of specially selected materials which shall be as uniform as possible for the entire job and shall be mixed in the proportion of one part cement to three parts sand or screenings; (crushed marble screenings will be preferred for facing mortar and unless otherwise specified this shall be used). These screenings or sand must not be too fine but should be from ¼" diameter down.

8. The finish of Ornamental Work such as balustrades cast in pieces or blocks shall preferably be obtained by casting same in a sand mould and with a facing of crushed marble or granite of a suitable color. After removal from the moulds they shall be tooled by means of revolving carborundum wheels or similar devices to remove the skin coat of cement.

9. Finish of the balustrade shall be finer than that of the balance of the work. Fine mouldings or other ornamental work shall always be made with a mortar face.

10. If a *Floated Finish* be specified a thin grout shall be put on with a wooden float, sufficient to cover the surface with a very thin coating and to fill all pores and cavities.

Waterproofing

1. Concrete which is desired to have water-resisting qualities shall be composed of a rich mixture of carefully graded materials so that the percentage of voids shall be as low as practicable, and should be laid as nearly monolithic as possible.

2. Waterproofing shall be done by one of three methods: first, mixing with the cement an impalpable material; second, covering the concrete with a waterproof coat of asphaltic nature; and third, laying impregnated paper or felt against the concrete surface, called the membrane system.

3. If the Alum and Soap method be specified a 5 per cent solution of ground alum and water shall be prepared, and a 7 per cent solution of soap and water. The alum solution shall be mixed with the mortar to the amount of ½ the ordinary gaging water. The soap solution shall then be applied in amount required to obtain the desired plasticity. (From Prof. Hatt.)

4. If the use of Hydrated Lime be called for, 5% by weight (of the weight of the cement) of thoroughly hydrated lime shall be added to the mixing water or an equivalent amount may be mixed dry with the cement. Care shall be taken to insure that the lime be completely hydrated.

5. If waterproofing by means of a coating of Asphalt be specified, the work shall be done as follows: The surface to be coated shall be painted with asphalt reduced with naptha; then a thin layer of hot asphalt shall be applied and thoroughly mopped over; then a coat of asphalt and clean dry sand in the proportion of one part asphalt to three parts sand by volume; this coat to be thoroughly mixed in the kettle and spread on with warm smoothing irons, the finishing coat to consist of pure asphalt spread thinly and evenly over the surface and then sprinkled with gravel. The finished coat shall be ¾ inch thick.

All asphalt shall be of the best grade, free from coal tar or coal tar products. It must not volatilize more than one-half of one per cent under a temperature of 300° Fahr. for 10 hours. It must not be affected by a 20 per cent solution of ammonia; 35 per cent solution of hydrochloric acid; 25 per cent solution of sulphuric acid nor by a saturated solution of sodium chloride. It must not flow under 185° Fahr. nor become brittle above zero degrees Fahr.

6. If tarred felt waterproofing be specified, the work shall consist of three ply tar and gravel work, and, unless otherwise shown on the drawings, will be applied as follows:

1st. A coating of hot coal tar pitch, not less than five gallons to the sq. ft.

2nd. A layer of ordinary tarred felt weighing not less than 14 lbs. per square, placed on the pitch while hot and mopped with pitch when laid.

3rd. A layer of Hydrex, Tartex, or equal brand of felt mopped with pitch.

4th. A final layer of ordinary felt, same quality as first layer, after which the entire surface shall receive a coat of pitch.

All laps shall be at least 2 inches in direction of drainage.

All pitch shall be of the best quality of straight run coal tar pitch having a melting point of about 140° Fahr.

7. Expansion Joints will always be waterproofed, preferably by keys of asphalt in the case of walls, or by lead covers and filling of asphalt, or by covering carefully with felt layers if the membrane system be used.

8. Patented compounds and methods of waterproofing shall be used only when covered by a guarantee satisfactory to the Engineer.

Laying Concrete in Freezing Weather

1. Concrete shall not be laid in freezing weather except by special arrangement with and under the supervision of the engineer in charge.

2. In case it becomes necessary to lay concrete in freezing weather, the following precautions shall be observed:

(1) The aggregate must be free from frost.

(2) Ten per cent excess of cement shall be used.

(3) Quick setting cement shall be preferred.

(4) The amount of water shall be not more than is actually required for the proper placing and setting of the cement.

(5) Common salt known as No. 2 grade shall be used to the extent of one-fifth of one per cent for each degree of temperature (Fahrenheit) under 32 degrees. This salt shall preferably be mixed with the mixing water and the amount specified is equivalent to 1¼ pounds of salt for each barrel of four cubic feet capacity and for each degree of temperature below 32 degrees. Calcium chloride may be use instead of salt if desired.

If desired, salt may be added to only a certain portion of the mixing water, in which case the concentration of the salt solution given above shall be increased by the ratio of the total amount of water used to the amount of salt solution used.

The amount of mixing water may be assumed at one cu. ft. for each bag of cement for ordinary reinforced concrete work.

(6) All concrete shall be protected for at least twenty-four hours after laying, preferably by covering with tarpaulin, straw or similar material.

3. If it be found necessary to lay concrete in temperature below 20° Fahr. the engineer may require in addition to the above requirements that the aggregate and also the mixing water be warmed before mixing. The mixing water shall not be warmed above 80 degrees Fahr.

4. When concrete is laid in freezing weather, great care must be taken to be certain that the concrete has attained sufficient strength before the removal of centers and no set rule for the removal of forms under these conditions can be followed.

5. Wherever possible, it is desirable that the concrete should be heated after placing by means of salamanders or other arrangements for supplying artificial heat.

Inspection and Tests

1. All materials will be subject to inspection by the Engineer in charge or his authorized assistant, and to such tests as the Engineer may make.

2. The Engineer may in addition to the Standard Tests of Cement cause to be made, *Short Time Tests of Cement* in contingencies where it may become desirable to use the cement before it is possible to complete the standard tests, but unless otherwise arranged in writing, the Contractor will remain responsible for the quality of the cement until the same is accepted by the Engineer after making the final tests.

Short time tests shall consist of the frequent preparation of pats and balls of cement and mortar and the approximate determination of the time of setting and of the strength from them. Some of the pats will be put into water as soon as sufficiently set and the water raised to the boiling point and allowed to boil for two hours. The quality may then be judged by the appearance and by the fracture. In addition the Engineer may cause to be determined by the usual methods, the weight and fineness of the cement. The Engineer may at his discretion give the Contractor written acceptance of the cement on the results of such tests only.

3. The Engineer will have an Inspector on the work, whose duties will be to see that these specifications, the plans and contract are faithfully fulfilled and that all work is of a strictly first-class character.

4. On the completion of the work and before it has been accepted, the Engineer may cause final tests to be made by loading the structure with twice the specified live load applied statically or with the specified live load applied at the highest rate of speed. These tests will not be made on concrete less than 30 days old. The static load shall be held in place not less than 24 hours. Under such loads there shall be no perceptible cracking of the concrete in tension, no deflection of the beams exceeding the calculated amount determined in accordance with the formula given under section D nor any other indication of weakness in any part of the structure.

5. In the event of the partial or total failure of the structure under final tests, or any other conditions during construction, then the responsibility for the failure or defect shall be fixed by agreement between the Engineer and the Contractor, and in the event of their failure to agree, by the Board of Arbitration provided for herein, and if the Contractor be held responsible, he shall make good all such defective work, and if he be not held responsible, the Owner shall pay for all such extra work at cost to the Contractor.

6. In the event of failure of any part of the structure under test, the Engineer may require tests to be made of all such other parts as he may deem advisable, the expense of such tests to be borne by the party held responsible for the failure.

7. When the Contractor is responsible for the design as well as the construction of a structure, he alone will be held responsible for all failures under tests or during construction.

Reinforced Concrete Slabs, Beams, Girders, Columns and Trusses

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1. Reinforced concrete *Slabs* will preferably be used for all spans up to about twenty (20) feet and reinforced concrete slabs supported by beams and girders for all spans from 20 to 40 feet depending upon conditions of loading and supporting.

2. Reinforced concrete slabs will also be preferred for the floor system of steel bridges.

3. Reinforced concrete slab, beam, girder and column construction will be preferred for elevated railroads, highway viaducts, especially where same cross railroad tracks, trestle construction, etc.

4. Reinforced concrete for slab, beam, girder and column construction and for all other types of reinforced concrete construction will, unless otherwise specified, be proportioned as follows: for carefully screened stone or gravel concrete, one part Portland cement, two parts sand and four parts broken stone, Mix No. 6; for slag concrete one part Portland cement, two parts sand, and three parts slag, Mix No. 5. The materials to be of the quality and sizes as herein described.

5. The sizes of broken stone or slag for use in reinforced concrete, slab beam, girder and column work shall not exceed one inch for large work nor three-quarters inch for small work.

6. When reinforced concrete columns are exposed to probable injury by vehicles, etc., they shall be protected for a height of four feet from the ground, preferably by metal forms of structural steel or cast iron, or by Wainwright corner bars, or equal.

7. When *Through Girders* or beams carry slabs or beams attached near the lower edge, they shall be provided with stirrups at such points sufficient to carry the applied load to the upper part of the girder, such stirrups to be suitably anchored to the slab or beam or other satisfactory provision shall be made.

8. The deflection of reinforced concrete slabs shall not exceed 1/360 of the span, either when tested with the specified load, or when the deflection is computed as provided for in Section D. Beams and Girders shall not deflect more than one-half this amount.

9. See assumptions for designing (Section B), for limitations of tee beams, etc.

10. All slabs, beams, and girders must be considered as continuous over supports unless provision be made to insure that they will act as simple beams.

11. Provision shall be made for expansion at distances not greater than 100 ft. apart in all slab, beam and girder construction when the reinforcing in such direction is not less than ½ of 1% of the concrete section.

For concrete not reinforced continuously in two directions expansion joints shall be provided at distances not exceeding 50 feet apart in the direction in which the concrete is not reinforced.

12. *Reinforced Concrete Trusses* will be designed in such a manner that the tensile stresses will be entirely resisted by the steel and the compressive stresses as far as practicable by the concrete.

13. As far as possible, they will have no eccentric connections, and the tension bars must be anchored at the connections in such a way as to develop their full stress without producing bending moment about the joints, unless such moments be carefully determined and provided for.

14. Contractors submitting plans for reinforced concrete trusses must submit complete stress diagrams giving all sizes of material and all stresses.

15. In general reinforced steel construction for trusses will be preferred to reinforced concrete.

16. Concrete used for trusses of reinforced concrete or reinforced steel shall not be leaner than 1-2-4 and preferably should be 1-1½-3 with maximum size of stone not greater than ¾ in. Unless otherwise specified, these latter proportions will be required.

17. When slabs, beams, girders, or other parts are made in units in an established factory, the formulae given herein for the design and proportioning thereof may be disregarded, at the option of the Engineer, and the results of tests may be used.

In such cases all units shall be subject to testing under the direction of the Engineer at the Contractor's expense, the number of such tests and manner of testing to be agreed upon between the Contractor and the Engineer. All such tests must show a safe carrying capacity equal to at least three (3) times the specified live loads, without cracking the concrete on the tension side, and an ultimate capacity of at least five times the specified live load.

Reinforced Steel Construction

1. When the steel reinforcing is so designed that it will carry in itself, without support from the encasing concrete, a definite proportion of the load, all parts of the steel construction shall be designed to carry such load, using the specifications of the American Bridge Co. or the "General Specifications for Steel Bridges" by Wilbur J. Watson, for unit stresses and workmanship.

2. In addition to its portion of the specified loads, the steel frame must also be proportioned to provide for all bending stresses due to the negative bending moment, in the case of partially continuous construction, or the bending moments due to eccentric loads.

3. The steel must also be sufficient to resist all tensile stresses due to the full load.

4. The concrete must be so proportioned as to provide the additional resistance required for the balance of the load, in conformity with the requirements of the other sections of these specifications.

5. Unless special provision is made to develop continuity, all beams and girders of reinforced steel construction shall be computed as simple beams.

6. *Forms* for reinforced steel beams, girders and columns may be removed in two-thirds (2/3) the time specified for monolithic reinforced concrete construction when the steel frame is proportioned to carry the full dead load then in place without assistance from the concrete.

7. In general, reinforced steel construction will be preferred for all through girders designed for railroad and electric railway traffic, for long span bridges designed for highway traffic and for all columns for all classes of bridges, whose length exceeds eight (8) times the least side or diameter.

8. In reinforced steel construction the occurrences of large flat surface of steel shall be avoided as far as is practicable, and in no case shall a single surface exceed 6 inches.

9. Angles placed back to back shall be separated a distance at least twice the maximum diameter of stone used in the concrete.

10. All flat surfaces of steel shall be covered with concrete not less in thickness than 1/3 the width of the surface so covered, and shall be wrapped with expanded metal or wire cloth, when exceeding three inches width.

Cast Stone and Blocks

1. Cast stone shall be used wherever shown on the drawings for ornamental work, balustrades, parapets, etc.

2. Cast stone shall preferably be cast in a sand mold in an established factory, and all exposed surfaces shall be dressed by hand, by means of revolving carborundum wheels, or similar devices used in such factories to produce tooled or other good stone finish. At least one-twelfth of an inch of such surfaces shall be removed.

3. When cast stone is tamped into a rigid mold, dressing of exposed surfaces will always be required.

4. When any cast stone exceeds in any dimension six times its least dimension it shall be properly reinforced to insure safety in handling, such reinforcing to be not less than one-half of one per cent of the cross section at right angles to the line of reinforcing.

5. The proportion of cement to aggregate in cast stone and blocks must not be less than 1 to 6 nor greater than 1 to 4 and the aggregate must not be too fine but should be of graded sizes from $\frac{3}{8}$ inch diameter down.

6. Aggregates for cast stone shall preferably be made by crushing whole pieces of such material as granite and marble and not over 40 per cent should pass a 1/16 mesh screen. Aggregates should be mixed with the cement in a mixer, preferably of the rotary type, with not less than 12 per cent of water by weight. If it is to be cast in sand molds it shall be constantly agitated from the time it is removed from the mixer until it is distributed in the mold.

7. Building blocks shall be used wherever shown on the drawings and shall be strong, well cured, dense, have good edges, shall show a strength of at least 1,200 pounds per square inch at 28 days and an absorption of not over five per cent by weight when thoroughly dried and immersed in water for 48 hours.

8. The Contractor shall furnish and place on file with the Engineer, with the bid, *Samples* of the concrete blocks and cast stone proposed to be used, which shall be satisfactory to the Engineer, and the blocks and stone used must conform in every way to such samples.

9. No broken, chipped, or checked blocks or castings will be allowed to be used in the work and all blocks or castings shall be carefully protected from injury. By checked blocks are meant blocks showing fine hair checks on the surface.

10. All cast stone must be provided with suitable *Dowels* and anchors for securing same to the work and all cast stone and blocks must be laid up in white or non-staining Portland cement mortar.

Concrete Arches

1. All *Arches* must be computed and proportioned in accordance with the regulations given under sections B and C and complete stress diagrams must accompany all plans.

2. All arches must be assumed to be subject to a *Range of Temperature* from + 20° to + 90° Fahr. for latitude 40. For other latitudes the limit must be increased for higher and decreased for lower latitudes, and provision must be made for expansion and contraction due to this change at the crown and at the piers.

3. In general the following proportions will be used in Arch Construction:

(a) for the *Arch Ring,* for light spandrel walls, for light spandrel arches, etc., one part Portland cement to two parts sand to four parts stone, Mix No. 6.

(b) for *Heavy Spandrel Walls,* and for light piers, and wing walls, one part Portland cement to two and one-half parts sand, to five parts stone, Mix No. 7½.

(c) for *Heavy Piers,* wing walls, etc., of massive concrete, one part Portland cement to three parts sand to six parts stone, in which may be imbedded twenty-five per cent of one-man stones. Mix No. 11½.

(d) for *Heavy Footings* of massive concrete, one part Portland cement to three and one-half parts sand to seven parts stone, in which may be imbedded twenty-five per cent of one-man stones, Mix No. 13, or Mix No. 11½ may be used with Puzzolan cement or Mix No. 6 with natural cement.

4. In general the arch rings of concrete arches shall be laid in *Transverse Sections,* laying the crown section first, then the sections at the quarter points and filling in between. The voussoirs thus formed must be provided with *Keys* equal in depth to one-quarter of the depth of the arch ring.

5. The Crown thickness of reinforced arches shall be not less than 1/50 of the span, nor the thickness at the springing point less than 1½ times the crown thickness.

6. The reinforcing *Steel* for reinforced concrete arches shall not be less than three-quarters of one per cent of the crown section.

7. The *Spandrel Walls* shall be securely anchored to the arch rings by means of proper dowels, and the arch ring reinforced transversely sufficiently to provide for the maximum lateral thrust on the spandrel walls.

8. The spandrel walls shall not be concreted until the wedges have been struck from under the centering.

9. Reinforcing bars for arch rings must extend below the springing plane a sufficient distance to develop the full strength of the bar by adhesion.

10. All earth covered arches must be waterproofed.

11. In case *Hinged Arches* are used, the hinges will preferably be of annealed cast steel, imbedded as much as practicable in the concrete and effectively anchored thereto.

12. In case *Ribbed Arches* are used each rib shall be considered as a beam to resist the bending stresses and the thrust, and in case full spandrel braced concrete arches are used, the

spandrels shall be considered only as assisting in the resistance to bending and the rib shall be sufficiently strong to resist the direct thrust. In the case of full spandrel braced arches the span and rise may be taken as the span and rise of the intrados, and the non-elastic theory be used in computing.

13. Arches must be fully analyzed, preferably by methods of analysis based upon the elastic theory of the arch and at least two conditions of live load must be assumed:

First, the live load covering the entire arch.

Second, live load covering one-half the arch. For large or important structures, additional positions of the live load should be assumed.

The method developed by Prof. Cain is recommended (Van Nostrand Science Series) or Principles of Reinforced Concrete Construction by Turneaure & Maurer.

14. All arch rings must be of sufficient thickness so that the resultant line of pressure as found by the methods prescribed in the preceding article will not pass outside of the middle third of the arch ring or else they must be reinforced.

15. The fill over arches shall be thoroughly compacted, and shall not be placed in less than two weeks after the completion of the Arch ring.

Centers shall not be struck until the fill is in place.

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Retaining Walls, Abutments and Piers.

1. In the design of reinforced concrete retaining walls, the lateral pressure due to the back filling shall be ascertained by means of Rankine's method of analysis, assuming the weight of ordinary earth fill as equal to 100 lbs. per cubic foot. The resultant of the lateral pressure shall be assumed to act at a point 1/3 the height of the wall, from the base.

2. In the case of massive concrete vertical retaining walls, the width of the footing should not be less than 30% of the height for walls not surcharged to 40% for walls which are surcharged.

For walls which carry heavy electric railway or steam railroad traffic, the ratio of width of footing to height of walls shall never be less than 4/10, except as may be shown on the drawings.

3. For reinforced concrete retaining walls, the same relation of width of footing to height of wall as given above may be used provided that approximately 1/3 of the width of the wall lies in front of the abutment and 2/3 to the rear. When a greater proportion than this is in the rear of the abutment, the ratio of depth to height must be increased.

4. Whenever the material back of a retaining wall is subject to saturation with water, the wall must be designed to resist the full theoretical hydraulic pressure.

5. Instead of Rankine's theory, retaining walls may be computed by means of the use of an equivalent fluid pressure which may be taken at from 13 to 33 pounds per cubic foot, according to the nature of the material and the nature of the surcharge load.

6. In using Rankine's theory for retaining walls which are used to support a non-surcharged fill, but which are subject to use as abutments for railroad bridges or other structures carrying heavy loads upon the top of the back fill, such walls shall always be computed as though supporting a sur-charged fill.

7. In the design of concrete retaining walls and similar structures account must be taken of the expansion and contraction due to temperature changes. The coefficient of expansion due to temperature changes shall be taken as .000006. A range of at least + or — 30° from a mean temperature shall be assumed, and expansion joints shall be provided at intervals not exceeding 50 ft. This distance may be increased if longitudinal reinforcing be used and walls may be built without expansion joints if the ratio of the longitudinal reinforcing steel to the area of the concrete equals or exceeds ½ of 1%.

8. *Sea Walls* or other retaining walls which may be subjected to saturation of the back fill shall be proportioned to resist the fluid pressure due to the action of a fluid equal in weight to the weight of the filling material.

9. Sea Walls subject to wave action must be proportioned to resist the pressure of a head of water equal to twice the greatest wave height.

10. Sea Walls and all other concrete construction in salt water shall be composed of a dense mixture, corresponding to that herein specified as No. 6 mixture and the cement shall be one which shall have shown its fitness for use in salt water. The mixture should be wet and well churned and, where praticable, pozzulana or trass should be used in the aggregate.

11. Massive concrete abutments will be preferred for all cases requiring a heavy mass, and reinforced concrete in cases where heavy mass is not required.

12. The type of abutment to be used, whether wing, straight, T or U type, will be indicated on the drawing.

13. All abutments must be designed to resist the thrust of the backing, in combination with such other forces as may come upon them, without exceeding the unit loads and stresses as given in section C.

14. In assuming the angle of repose of the back filling, a slope of 1 vertical to 1½ horizontal shall be assumed for loose dry earth or sand and a slope of 1 to 1 for carefully laid and compacted dry earth filling.

15. All abutments must be carefully drained, or if not possible to do this, they must be proportioned to resist the action of fluid pressure due to the back fill.

16. The faces of abutments will be given a batter unless otherwise shown on the plans, of an inch to the foot, and there will be provided a coping course under the bridge seat in the case of abutments for steel bridges, which will, unless otherwise shown on the plans, be sixteen inches deep and project four inches.

17. Back walls for abutments of steel bridges must have a thickness at the base of at least one-half their height or else be reinforced.

18. In general *concrete for abutments* will be mixed in the proportion of one part Portland cement to three parts sand to six parts broken stone, mix No. 9, for massive concrete and imbedded stone (Rubble concrete) may be used if so indicated on the drawing, or permitted (in writing) by the Engineer in charge.

19. Natural cement concrete, mix No. 6, may be used for foundations or in other places where it will not be subject to action of the atmosphere nor to running water, if so indicated on the drawing, or Puzzolan cement concrete, mix No. 7½, may also be so used.

20. The Bridge Seats shall be mix No. 4½ concrete of Portland cement one part, hard sand one and one-half parts, and hard stone three parts.

21. All Anchor Bolts for steel superstructure when used shall be furnished by the owner and set by the Contractor.

22. *Concrete Piers* shall in general be constructed of massive concrete in all cases where they are liable to be submerged in water, in order to obtain the greatest possible weight.

23. The Mixtures to be used in concrete piers shall be the same as those used in abutments.

24. The Pressure of ice against concrete piers shall be considered and shall be taken as equal to the water line on the exposed side into the maximum depth of ice for that latitude and multiplied by 1,000 lbs. per sq. foot.

25. Piers shall also be proportioned to withstand impact from floating logs or other forces to which they may probably be subjected.

26. Piers shall be given a batter of one in twenty-four, unless otherwise specified, also copings of similar construction and mixtures to those for abutments.

27. The hydraulic uplift of water penetrating underneath the footing of piers shall be considered.

28. All footings shall, wherever practicable, be laid free from water and no concrete footings will be laid in water except by special arrangement with the Engineer.

29. Footings having heads of piles imbedded therein, shall have the contents of the imbedded piles deducted in computing contents of masonry.

30. Reinforced concrete footings shall be designed in accordance with the provisions of preceding sections, but no reinforcing shall be placed at a less distance than 4 inches from any concrete surface.

31. The reinforcing shall be so arranged as to distribute the loads equally on the foundation.

32. Reinforced concrete footings shall always be of Portland cement concrete mix. No. 6 or 7½ as specified on the drawing.

33. In estimating the excavation for footings, the size of excavations shall be taken as equal to the neat size of the footings, and no allowance will be made for additional excavation.

34. Unless otherwise agreed upon the price bid by the Contractor for the footings shall include all Sheeting, Pumping, Cofferdams, Bracing, etc., required to keep the pits open and free from water while depositing concrete, the removal of same, and backfilling to the original level of the ground.

Concrete Piling

1. *Concrete Piles* will be divided into two classes: first, concrete piles moulded in forms and driven to place, and second, concrete piles formed in place. The former must be sufficiently reinforced to withstand handling and must be provided with proper cushions for driving and will be entirely at Contractor's risk. They must be driven to elevations as given by the Engineer, or else they must be cut off to such elevations. Piles of the second class will preferably be of the "Simplex" or "Raymond" patented types, as indicated on the drawings.

2. The Contractor shall at his own expense, and under the direction of the Engineer, test the number of test piles called for by the plans, which will be, in general, only one pile for each different kind of foundation encountered, by loading to the specified loads without exceeding a settlement of one-quarter inch, unless otherwise specified on the drawings or herein.

3. The ordinary formulas for determining the bearing power of timber piles will not be applied to concrete piles.

4. The number of piles required may be changed by the Engineer after the test has been made for bearing power, and such change shall not affect the price per lineal foot bid, provided that the change does not exceed 25% of the total length of piles, and in the case of lump sum bids, the amount to be paid shall be to the amount bid in the proportion of the total length of piling used, to that shown on the plans, provided that such change does not exceed 25% of the quantities shown on the contract drawings.

5. All piles shall be straight and a variation from a straight line exceeding 1 in 24 shall be cause for rejection of the piles. No allowance will be made for the side pressure of earth in holding piles in line, when they are computed and loaded as concrete columns.

6. The maximum allowable load on concrete piles shall not exceed 300 lbs. per sq. in.

When the principal resistance to settlement is from the side or skin friction of the pile, this allowable load may be computed upon the average diameter of the imbedded pile.

When concrete piles act as columns, the allowable load shall be computed upon the minimum cross-section of the pile.

General Conditions and Requirements

1. If required by the Owner, the Contractor shall furnish a bond in the sum of one-fourth of the amount of his contract with a satisfactory surety company as surety that the contract will be fulfilled.

2. Should there be any discrepancy between the drawings and specifications, between scale or full size drawings, or between scale of the drawings and the figures on the same, the matter shall be referred to the Engineer, and his decision shall be followed.

3. The Engineer will give all datum lines and levels necessary for the prosecution of the work and be responsible for the accuracy thereof.

4. The Contractor shall give to the proper authorities all requisite notices relating to the work in his charge and shall conform to all laws and ordinances affecting same, shall obtain all official permits and licenses required and pay all proper fees for same, and he shall pay for any other legal charges from city, county, state or federal officers.

5. The work shall be suitably protected by red cautionary lights at night, and by watchmen, if necessary.

6. The execution of the work will be entirely at the Contractor's risk and he will be liable for its safety. The Contractor will be liable for all cases of personal injury which may occur during the progress of the work for which either the Owner or the Contractor might become liable.

7. All royalties for patents or claims for the infringement thereof that may be involved in the construction of this work shall be included in the contract amount, and the Contractor shall satisfy all demands that may be made at any time for such royalties and be liable for any damages or claims for infringements of patents.

8. At periods not less than thirty days apart, on the request of the Contractor, the Engineer will make estimates of the value of material furnished and labor performed, and the amount of such estimates less 10 per cent will be paid the Contractor by the Owner within 30 days after such estimate has been presented for payment.

The final payment will be made in 60 days after the completion of the work and the acceptance thereof by the Engineer on behalf of the Owner.

9. Or if so stated in the contract, a single payment for the whole shall be made within 30 days after the completion of the work and its acceptance by the Engineer on behalf of the Owner.

10. The Contractor shall remove from the site all debris and rubbish, at such times as may be directed by the Engineer.

11. The work will be done under the general direction and supervision of the Engineer, and his interpretation of the drawings and specifications shall be final, subject to the provisions of the Arbitration Clause.

The Engineer will furnish such additional drawings and explanations as may be necessary.

12. No alterations will be made in the work or plans except by written order of the

Engineer and the amount to be paid by the Owner or allowed by the Contractor for such alterations must be stated in such order. Should the Owner and the Contractor fail to agree as to the amount to be paid or allowed, the work shall go on under the order required above, and the determination of said amount be submitted to arbitration as herein provided for.

13. Should the Contractor at any time refuse to supply a sufficiency of properly skilled workmen or of materials of the proper quality or fail in any respect to prosecute the work with promptness and diligence, or fail in performance of any agreements herein contained, such refusal, neglect or failure being certified to by the Engineer, the Owner shall be at liberty, after three days written notice to the Contractor, to provide any such labor or materials and to deduct the cost thereof from any money then due or thereafter to become due to the Contractor under this contract; and if the Engineer shall certify that such refusal, neglect or failure is sufficient ground for such action, the Owner shall also be at liberty to terminate the employment of the Contractor for the said work and to enter upon the premises and take possession for the purpose of completing the work included under this contract of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work, and to provide materials therefor; and in case of such discontinuance of the employment of the Contractor he shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the Owner in finishing such work, such excess shall be paid by the Owner to the Contractor, but if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner. The expense incurred by the Owner as herein provided either for furnishing the materials or for finishing the work, and any damage incurred through such default, shall be audited and certified to by the Engineer, whose certificate thereof shall be conclusive upon the parties, subject to the Arbitration Clause.

14. Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner, of the Engineer or of any other Contractor employed upon the work by the Owner, or by damage caused by fire or other casualty for which the Contractor is not responsible, or by general strikes or lockouts, caused by the acts of employees, then the time herein fixed for the completion of the work shall be extended for a period equivalent to the time lost by any or all of the causes aforesaid, which extended period shall be determined and fixed by the Engineer, but no such allowance shall be made unless a claim therefor is presented in writing with the Engineer within forty-eight hours of the occurrence of such delay.

15. The Owner agrees to provide all labor and materials essential to the conduct of the work not included in this contract in such manner as not to delay its progress, and in the event of the failure so to do, thereby causing loss to the Contractor, agrees that he will reimburse the Contractor for such loss; and the Contractor agrees that if he shall delay the progress of the work so as to cause loss for which the Owner shall become liable, then he will reimburse the Owner for such loss. Should the Owner and the Contractor fail to agree as to the amount of loss comprehended in this article, the determination of the amount shall be referred to arbitration, as provided for in Article 17.

16. It is further mutually agreed between the parties hereto that no certificate given or payment made under this contract, except the final certificate or final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials.

17. In case the Owner and the Contractor fail to agree in relation to matters of payment, allowance or loss referred to, or should either of them dissent from the decisions of the Engineer referred to, which dissent shall have been filed in writing with the Engineer within ten days of

the announcement of such decision, then the matter shall be referred to a Board of Arbitration to consist of one person selected by the Owner, and one person selected by the Contractor, these two to select a third. The decision of any two of this Board shall be final and binding on both parties hereto. Each party shall pay one-half of the expense of such reference.

18. If the work be not completed on or before the date mentioned in the contract for such completion, then the Contractor shall reimburse the Owner for all losses or damages or expenses, including expense of engineering and inspecting to which the Owner may be subjected by reason of such delay.

19. The Engineer's drawings and these specifications are intended to be supplementary to each other, and the specifications given on the drawings shall have full force as if given in these specifications, and in case of conflict between the two, specifications as given on drawings shall be taken as superseding these specifications.

20. The contract drawings shall be signed by both parties to the contract, and shall be considered together with the specifications as part thereof.

21. All drawings prepared and notes obtained by the Engineer will remain the property of the Engineer unless otherwise specifically arranged with the Owner.

22. The Contractor will provide proper sanitary conveniences for the workmen.

23. Clauses written in ink in these specifications will supersede all printed clauses with which they conflict.

24. Contractors submitting their own plans for any class of work covered by these specifications shall submit complete drawings showing the size of each main member in the proposed work and the arrangement of all the members. Such plans must conform to all of the requirements for computing, proportioning, etc., given in these specifications.

25. The word "Engineer" as used herein refers to the Engineer employed by the Owner or his authorized assistants.

26. The Engineer shall have power to condemn any and all work which does not, in his opinion, meet the requirements of the specifications, and all work so condemned shall be immediately removed by the Contractor and made good.

27. The Contractor shall place and maintain sufficient protection at all points where the structure is liable to damage or disfigurement during the construction of the work.

Portland Cement Sidewalks, Curbs and Roadways.

1. Portland Cement sidewalks on bridges shall, unless otherwise shown on the drawings, consist of reinforced concrete slabs. These slabs shall be computed for the actual dead load and required live loads.

Expanded metal or woven or welded wire mesh will, in general, be preferred for the reinforcement of sidewalk slabs.

The sidewalks will be finished with a top layer of a thickness as shown on the drawings, but not less than ¾″ thick, of mortar composed of the same brand of Portland Cement as used for the slabs, one part; sand one and one-half parts, and quarter inch stone two parts; or two and one-half parts well graded sand may be used instead of the sand and stone.

The top layer shall be placed before the concrete in the slab has set, shall be well rammed, using care to insure a perfect bond with the slab, and the surface shall be well worked and floated with straight edge and float.

The walk shall be divided into blocks not larger than five feet square. The surface shall be finished by grooving or scoring with special tools, taking care to avoid a smooth glass finish, and to obtain a gritty finish that will not be slippery.

2. All sidewalks of Portland Cement shall be finished by workmen especially skilled in the art.

3. Portland Cement sidewalks on approaches to bridges will not usually be considered part of the bridge contract, but when they are so specified, they shall be built with a surface finish similar to that described for sidewalks on the bridge, laid on a base prepared as follows:

After the subgrade has been properly prepared and thoroughly drained with porous tile, a bed of sand and gravel or cinders shall be placed thereon, thoroughly wet and rammed and finished to grade. The bed will be six (6) inches in thickness.

Upon the prepared bed shall be laid a four inch concrete slab, composed of one part Portland Cement, 2½ parts sand and five parts broken stone in size from ⅜″ to 2″.

The top layer ¾″ thick will be laid immediately upon this layer before the latter has set.

4. All materials shall conform to standard specifications for the same. The cement to be American Portland Cement of well known make and subject to the specifications of the American Society for Testing Materials and to the Standard Tests, the sand shall be clean, well graded, and the stone hard, clean and durable. The Engineer may require the sand and stone to be either screened or washed, or both, at his discretion. Materials shall conform to requirements of preceding sections.

5. Exposed edges of sidewalks shall be protected from injury where necessary.

6. Concrete curbs on bridges will be laid at the same time as the sidewalk slabs, when used, and also at the same time as the gutters, when the latter are made of Portland Cement concrete.

The proportions will be the same as specified for the sidewalk slabs, or unless otherwise shown or specified, will be composed of No. 6 mix. (1:2:4).

The finish will be made to conform to that of the sidewalk.

7. All concrete curbs on important bridges will be protected by the Wainwright steel curbing, or equal, as may be decided by the Engineer and shown on the plans.

8. Concrete curbs on approaches will be built in a similar way to that described above, the depth not to be less than 20″ deep and 4″ thick, and bedded on a 6 inch bed of gravel or cinders.

9. When concrete sidewalks or curbs are laid on a newly placed fill exceeding 2 ft. in depth, there shall be provided metal reinforcement placed ¾″ in from the under side of the slab and two inches from the under side of the curb, the area of such reinforcement to be not less than one two-hundredth of the cross sectional area of the concrete.

Expanded metal or woven wire shall be preferred for the sidewalk; bars for the curbs.

10. When concrete gutters are called for, they shall be composed of one part Portland Cement, two and one-half parts sand and five parts broken stone (No. 7½ mix.) six inches thick unless otherwise shown on the plans, and extending two feet from the curb.

The surface shall be carefully floated and worked to grade.

When laid on approaches the gutter must be laid on a six inch fill of gravel or cinders, carefully wet and rammed as specified for the sidewalks.

11. Grades and slopes for sidewalks, curbs and gutters will be given by the Engineer.

12. Porous terra cotta tile will be required under all curbs, laid with a minimum slope of 3 inches in each 100 feet and with all joints protected by a double thickness of burlap wrapped around the joint.

13. When concrete pavements are used on filled arches or on approaches to bridges consisting of filled material or natural earth, the finish as hereinafter specified shall be laid upon a sub-base to be constructed as follows:

All materials shall be carefully excavated to a sub-grade uniformly eight (8) inches below the finished surface of the pavement. All soft or unsuitable material below the sub-grade shall also be removed and any excavation below the sub-grade shall be filled with concrete or carefully tamped sand, gravel or broken stone. Upon the sub-grade shall be laid a thoroughly rammed layer of No. 9 concrete (1:3:6) not less than six inches in depth. To mark the top grade of the concrete sound stones of suitable depth and size shall be set upon the sub-grade about twelve feet apart along the center and each side of the roadway, as the Engineer may direct.

14. Scuppers or catch basins will be furnished and placed as shown on the drawings. They will be of cast iron, not less than ¾″ thickness of metal, free from all defects, plugging or filling. They will be subject to hammer testing for soundness and toughness. They will be heavily coated with asphaltum fluxed with residuum oil, or such other preparation as may be acceptable to the Engineer.

15. Down spouts and drains will be furnished and located as shown on the drawings, and will be of wrought iron, unless otherwise shown.

16. Concrete pavements, when called for on the drawings shall consist of a wearing surface 2 inches thick proportioned and placed as specified for sidewalks, except that a rough finish will be required.

17. The wearing surface shall be placed before the base has set.

18. The surface shall be divided into blocks about 5″ x 9″ by grooves ¼″ deep.

19. The stone and sand for the wearing surface shall be carefully selected for hardness and resistance to abrasion.

20. Expansion joints shall be provided wherever such joints occur in the base, or are called for on the drawings.

21. Concrete pavements shall not be used on bridges carrying very heavy traffic.

22. When concrete pavements are used, the curbs shall be made 9 inches high to provide for future paving.

Brick Pavements for Bridges

1. When so shown on the plans, the roadways of bridges or bridge approaches shall be paved with brick.

2. All materials shall be carefully excavated to a subgrade uniformly below the required surface of the finished pavement, allowing for the depth of the brick, one inch sand cushion and six inches concrete. All soft, or unsuitable material below the subgrade shall be removed. Excavation or shrinkage below the subgrade shall be filled with No. 9 concrete which shall form part of the concrete foundation specified below.

3. Upon the subgrade shall be laid and thoroughly rammed for the full width between curbs a layer of No. 9 concrete (1-3-6) not less than six inches in depth at any point. To mark the top grade of the concrete, sound stones of suitable size and depth shall be set upon the subgrade about twelve feet apart along the center and each side of the roadway as the Engineer may direct. Such marking stones shall remain and form a part of the concrete foundation.

4. Upon the concrete foundation, prepared as specified, shall be placed a cushion of sand of such thickness that, after the brick are firmly bedded by rolling, the upper surface thereof shall be exactly at the required grade and the sand cushion about one inch thick. The cushion shall consist of clean, coarse sand or fine screened gravel, free from dirt or vegetable matter. The sand shall be slightly wet at the time the brick are laid.

5. Upon the sand cushion shall be laid repressed, vitrified, paving bricks of best quality, sound, hard burned, of uniform size, all from one manufactory, all of one color, made and burned especially for street pavements. They shall be homogenous in character and compact in structure, free from lumps of uncrushed clay or lamination fire cracks or checks of more than a superficial extent and when immersed in water for four days they shall not develop cracks nor spall. They shall be perfect in shape and shall be inspected as they come on the ground, and all imperfect or broken brick shall be removed from the work. The Contractor shall furnish, without extra charge, sufficient labor to handle the brick in such examination and culling.

6. All paving bricks shall satisfactorily endure the tests specified in the following paragraphs; all tests shall be made upon bricks to be selected by the Engineer from the bricks actually delivered by the Contractor at the site of the work.

7. Five bricks when placed in a foundry rattler, the diameter of which shall not exceed twenty-eight inches, with not less than one hundred pounds of foundry shot weighing not more than one-quarter pound each, shall be revolved at the rate of not more than twenty-five revolutions per minute for one and one-half hours. Each brick shall be weighed at the end of one-half hour and again at the end of the test and shall not show a loss of more than three per cent of its weight during the last hour of the test.

8. When dried for twenty-four hours at a temperature of not less than 212 degrees Fahrenheit and then immediately immersed in water for twenty-four hours, no brick shall absorb more than three per cent of its weight.

9. No paving brick shall crush under a load of 10,000 pounds per square inch when tested on edge.

10. The bricks shall be laid on edge at right angles to the street or as directed by the Engineer. Each alternate course shall commence with a half brick, but half bricks or bats shall not be used except at the ends of courses.

11. All longitudinal joints shall be broken with a lap of not less than three inches. The joints shall be laid tight and all bricks shall be laid by skilled workmen who shall stand on the brick already laid. In no case shall the sand bed be disturbed after being brought to the exact subgrade and crown of the street.

12. After the bricks are laid, they shall be rolled to the proper surface with a roller weighing not less than five tons.

13. The entire surface shall be closely inspected, brick by brick, by a skilled workman, who shall remove any brick which may be found chipped or broken, or irregular in shape or not a perfect fit, or not to exact surface, and who shall remedy such defective spots if found.

14. The joint next to the curb shall be ⅝ inch wide and filled before the balance of the roadway is grouted with bituminous cement which must not run at a temperature of 100 degrees Fahr. or become brittle at zero degrees Fahr.

A similar transverse joint shall be made at all expansion joints in bridges and over the crown of all arches.

15. The entire surface shall finally be flushed and the joints filled with Portland cement grout in the following manner: First, a pure thin grout shall be formed of one part of cement to one of clean, fine sharp sand, and the whole surface shall be flushed with this from a portable grout box, care being taken to fill all the joints. Afterwards a thicker grout, formed of the same proportions of cement and sand with just enough water to enable it to run, shall be brushed into the joints with stiff brooms and the pavement shall then be completely covered with sand and left undisturbed for not less than six days before being thrown open to traffic.

Before the final acceptance of the work, the contractor shall sweep the street clean and remove the sweepings.

16. The top surface of the finished pavement shall conform accurately to the grades and pitch to be given by the Engineer.

17. When brick pavement are laid on bridges, the floor of which forms a base for same, the one inch sand cushion shall be laid directly on such base.

18. When brick pavements are laid on a shallow, carefully compacted fill over concrete arches, the concrete base may be omitted, if so indicated on the plans.

19. The contract price of brick pavement shall include the cost of all labor and materials required to prepare the subgrade and lay the concrete foundation, the sand cushion and the brick surface as specified in the preceding paragraphs. Payment will be made for the actual number of square yards of brick pavement measured in place.

20. When the rails are laid in brick pavement, special shaped brick shall be used against the rails.

21. The contractor must file sample brick with his bid or else must name some well known brand which he will use.

Asphalt Block Pavement.

1. The blocks shall be five (5) inches in width by twelve (12) inches in length by three (3) inches in depth and a variation one quarter (¼) of an inch from these dimensions will be sufficient ground for rejecting any block.

2. The blocks must be composed of the following materials:

Asphaltic cement	9 to 13 per cent.
Conglomerate copper sands (see note)	76 to 62 per cent.
Limestone Dust	15 to 25 per cent.

3. The copper sands in the blocks must be brushed so that every particle will pass a screen of ⅜ of an inch mesh. The blocks must receive a compression in the moulds of not less than two hundred (200) gross tons, and must weigh not less than fifteen (15) pounds per block. The blocks shall yield, when extracted with bisulphide of carbon and after the evaporation of the solvent, not less than six per cent, or more than eight per cent of bituminous matter.

Note.—Other sands may be used subject to the approval of the Engineer.

4. The asphaltic cement shall be composed of steam refined Trinidad "Lake" asphalt, and heavy petroleum oil, or other equally good flux. The refined asphalt and the flux shall be mixed in such proportions as will produce an asphaltic cement of a proper consistency and quality. The heavy petroleum oil shall be free from impurities and brought to a specific gravity of from 10 to 14 degrees Beaume and shall have a fire test of not less than 350° Fahr.; it shall contain an appreciable amount of light oils or matter volatile under 250 degrees Fahr. and the distillate at 400 degrees Fahr. for thirty hours shall be less than 10 per cent. Any other flux, if used, as a substitute for the heavy petroleum oil, shall also fulfill the above tests except that for specific gravity.

5. Upon the surface of the cement foundation shall be spread a bed of cement mortar one-half inch in thickness. This mortar bed shall be composed of Portland Cement as specified and sand as specified, and mixed in the proportion of one part cement to four parts sand. This mortar bed "shall be struck" to a true surface exactly parallel to the top of the finished pavement and three inches below it in the following manner:

6. On the surface of the concrete foundation shall be set strips of wood four inches wide by one-quarter inch thick, and of a length equal to the width of half width of the street, if practicable, or strips of steel four (4) inches wide by one-eighth or three-sixteenths inches thick and of a convenient length may be used. These strips shall be carefully set from curb to curb, to the exact crown of the street and imbedded throughout their length in mortar, so that the top surface of the strips shall be three inches below the grade of the finished pavement. An iron shod straight edge or "Striker" shall be used on two sets of strips, set as described above, eight or ten feet apart, to strike the mortar bed to a true and even surface. As soon as the bed has been struck up one set of strips shall be taken up and the trench carefully filled with mortar.

7. Upon this mortar bed the blocks shall be immediately laid with close joints and uniform top surface.

8. The blocks shall be laid by the pavers standing upon the blocks already laid, and not upon the bed of mortar.

9. The blocks shall be laid at right angles with the line of the street with such crown as the Engineer may direct; and in such a manner that all longitudinal joints shall be broken by a lap of at least four inches. The blocks shall be so laid as to make the lateral joints as tight as possible, consistant with keeping a good alignment of the courses across the street and the longitudinal joints shall be immediately closed by pressing each course in the direction of its length by lever. When thus laid the blocks shall be immediately covered with clean, fine dry sand, entirely free from any loam or earthy matter. This sand shall be swept over the surface until the joints are all filled and shall be allowed to remain on the pavement not less than thirty days or for such length of time as will allow the street traffic to thoroughly grind the sand into all the joints.

10. The price bid per square yard of Asphalt Block Surface must include the laying, and furnishing of all materials, labor and implements necessary to complete the wearing surface, including the mortar bed, as specified above.

11. When Asphalt block pavements are laid on filled or natural foundations requiring a sub-base, the base shall be prepared as follows:

12. All materials shall be carefully excavated to a sub-grade uniformly below the required surface of the finished pavement, allowing for the depth of the brick, one inch sand cushion and six inches concrete. All soft or unsuitable material below the sub-grade shall be removed. Excavation or shrinkage below the sub-grade shall be filled with No. 9 concrete which shall form part of the concrete foundation specified below.

13. When the sub-grade shall be laid and thoroughly rammed for the full width between curbs a layer of No. 9 concrete (1:3:6) not less than six inches in depth at any point. To mark the top grade of the concrete, sound stones of suitable size and depth shall be set upon the sub-grade about twelve feet apart along the center and each side of the roadway as the Engineer may direct. Such marking stones shall remain and form a part of the concrete foundation.

14. When the plans call for the asphalt block to be laid on a sand cushion, the sand shall be clean, coarse sand or screened gravel, slightly wet, and carefully screeded to grade.

And all other work shall conform to that specified for block laid directly on the concrete.

Asphalt Pavements on Bridges

1. Sheet asphalt pavements on bridges will generally be laid upon a concrete or asphalt binder base, which in the case of buckle plate floor construction shall never be less than one and one-half inches thick over the heads of projecting rivet heads and buckles.

2. When asphalt pavements are laid upon concrete sub-base the surface shall be carefully cleaned and roughened and a neat cement or other binding material be placed thereon and the asphalt binder and wearing surface to the depth of 2½ inches shall be immediately placed thereon.

3. The pavement shall be equal in all respects to the best grade of standard asphalt pavement which is being built by any established paving company at the time the pavement herein described is built.

4. When asphalt pavement is called for on filled approaches or other filled constructions, the said fill shall be carefully excavated or graded to a subgrade 8½ inches below the required surface of the finished pavement. All soft or unsuitable material below the subgrade shall also be removed and any excavation below the subgrade shall be filled with concrete or carefully tamped sand or gravel or broken stone.

5. Upon the subgrade shall be laid a thoroughly rammed layer of concrete (1-3-6) proportion, not less than 6 inches in depth. Upon this concrete base shall be laid the asphalt binder and wearing surface, 2½ inches thick.

6. The 2½ inch asphalt pavement shall be composed of two courses, the binder course and the pavement mixture or wearing surface.

7. The binder course shall be composed of clean, broken stone, gravel or slag of such size as will pass through a one inch ring.

8. The asphalt cement shall be composed of 100 pounds by weight of asphalt and about 18 pounds by weight of heavy oil, the quantity of oil will vary as may be necessary to produce the best results.

9. The broken stone, gravel or slag shall be heated and thoroughly mixed with asphaltic cement in such proportions as shall thoroughly coat the particles of stone, gravel or slag.

10. The mixture shall be spread on the foundations to such a thickness that after being compacted by a roller weighing not less than five tons, it shall have a thickness of one inch.

11. The pavement mixture will be laid immediately upon the binder course. It shall be brought to the work at a temperature of 250° Fahr. It will then be carefully spread by means of iron rakes in such manner as to give a uniform and regular grade and to such depth that after having received its ultimate compression, it shall have a thickness of two inches. The surface will then be compressed by a hand roller after which a small amount of cement will be swept over it and it will then be thoroughly compressed by a heavy steam roller, the rolling being continued as long as it makes an impression on the surface.

12. Where street car tracks are used, asphalt shall not be laid against the rail, but special shaped paving brick in full lengths and half lengths alternating shall be laid alongside the rails, and filled with asphaltic cement.

13. This paving brick shall be equal to that specified for brick paving and will be paid for at the same rate as asphalt paving.

14. Next to the curb the pavement will be coated over with pure hot asphalt for a width of 15 inches after the paving is completed.

15. The composition of the pavement mixture will be from 12 to 16 parts of asphaltic cement mixed with 67 to 73 parts of clean, sharp sand and from 15 to 17 parts of pulverized carbonate of lime.

16. The sand and asphaltic cement will be heated separately to about 300° Fahr.

17. The pulverized carbonate of lime while cold will be mixed with the hot sand in the required proportions and will then be mixed with the asphaltic cement at the required temperature and in the required condition with an apparatus suited to effect a perfect mixture.

18. The asphaltic cement will be composed of 100 parts of refined asphalt mixed with 12 to 15 parts of heavy petroleum oil.

19. Asphalt pavement shall be laid only by workmen experienced in that class of work.

If a guarantee is required, the Owner will deduct and retain from the final estimate or other estimates, an amount equal to   per cent of the amount due for paving, which money will be retained for a period of   years and if at the end of   years the Contractor shall have made good all defects which may have developed in the paving, the Owner will return to the Contractor the amount so retained.

20. Expansion joints must be provided in the base wherever shown on the plans.

21. When the asphalt pavement is laid directly upon concrete floor plates of bridges the base, as specified above, shall be omitted and only the 2½ inch thick pavement be required.

Specifications for Wood Block Paving

The wood blocks shall be either of Southern Longleaf Pine or of Southern Black Gum, not less than 90 per cent heart, of a texture permitting satisfactory treatment as hereinafter specified.

All blocks shall be of sound timber, free from bark, loose or rotten knots, or other defects which shall be detrimental to the life of the block or interfere with its laying. No second growth timber will be allowed.

The paving blocks cut from the timber above specified shall be well manufactured, truly rectangular and of uniform dimensions. Their depth (parallel to the fibre) shall be three (3) or three and one-half (3½) inches and as called for on the plans, their length shall not be less than six (6) nor more than eight and one-half (8½) inches, and their width shall be three (3) inches, but all blocks used in any one contract shall be of the same width, and of the same timber. The depth may vary not more than one-eighth (⅛) inch from the dimensions specified for any contract.

The blocks are to be thoroughly treated with a heavy or "dead" oil of coal tar. All parts of each individual block shall be thoroughly treated with such oil by the injection of not less than twenty (20) pounds of the oil to the cubic foot of timber.

In preparing the blocks to receive the creosote oil, they shall be placed in air tight cylinders, where by means of dry heat or heat produced bv superheated steam, in closed coils, and the use of a vacuum pump, all sap in the blocks shall be vaporized and all moisture in them removed. When the blocks are thoroughly dry and with a vacuum of twenty-three (23) inches in the cylinder, the oil shall be run into the cylinder at a temperature of 175 to 200° after which hydraulic pressure shall be applied and maintained until the blocks have absorbed and contain at least twenty (20) pounds of the oil to each cubic foot of wood.

The creosote oil or heavy or "dead" oil of coal tar shall conform to the following specifications when tested:

The specific gravity at 68 degrees F. shall be not less than one and ten-hundredths (1.10) when distilled in a retort with the thermometer suspended not less than one (1) inch above the oil, it shall lose not more than thirty-five (35) per cent, up to three hundred and fifteen (315) degrees.

The distillation shall be made with approximately 100 grams of oil in six ounce retort.

The oil shall be free from carbon and shall contain not more than two and one-half (2½) per cent of matter in suspension. The oil must be free from adulterations, it must be obtained wholly and entirely from coal tar and must not contain any oil derived from water gas tar, oil gas tar or other tars.

At any time after treatment the blocks shall show such waterproof qualities that, after being dried in an oven at a temperature of 120 degrees for a period of 24 hours, weighed, and then immersed in clear water for a period of 24 hours and weighed, the gain in weight shall not be greater than 4 per cent.

The blocks will be carefully inspected after thev are brought on the line of work, and all blocks which in quality and dimensions do not conform to the requirements of the specifications will be rejected and must immediately be removed from the street.

The engineer shall further have the right to make tests and examinations at the Contractor's

works of the materials proposed to be used, and to reject any and all such materials as he may consider not to be in compliance with these specifications.

When wood block pavements are laid on filled or natural earth or other material requiring a sub-base the base shall be prepared as follows:

All materials shall be carefully excavated to a subgrade uniformly below the required surface of the finished pavement, allowing for the depth of the block, one inch sand cushion (if used) and six inches concrete. All soft, or unsuitable material below the subgrade shall be removed. Excavation or shrinkage below the subgrade shall be filled with No. 9 concrete which shall form part of the concrete foundation specified below.

Upon this subgrade shall be laid and thoroughly rammed for the full width between curbs a layer of No. 9 concrete (1-3-6) not less than six inches in depth at any point. To mark the top grade of the concrete, sound stones of suitable size and depth shall be set upon the subgrade about twelve feet apart along the center and each side of the roadway as the engineer may direct. Such marking stones shall remain and form a part of the concrete foundation.

On the cement mortar surface, spaced and smoothed to the proper crown and grade, the blocks are to be laid with the grain vertical and at such an angle with the curb as the Engineer may direct; they shall be laid in parallel courses with as tight joints as possible; the joints shall be broken by a lap of not less than three (3) inches; each block being firmly imbedded in this mortar bed so as to form a true and even surface.

Before laying the blocks, a five-eighths inch plank shall be placed against the curb and the blocks laid up to this plank, after the blocks are tamped into place and before the joints are filled; this plank shall be removed and the joint between the blocks and the curb and the joints between the blocks for a distance of two feet from the curb outward towards the center of the street shall also be filled with an asphalt filler that will not flow at 120° F. and will not become brittle at zero F. and which shall remain ductile, shall be absolutely proof against water and street liquids, shall firmly adhere to the wood blocks and shall be pliable rather than rigid, thus providing for expansion and contraction.

This asphalt filler shall be heated and poured at a temperature of not less than 300 degrees F.

The remainder of the joints shall be completely filled with clean, dry, fine sand. If the sand is not dry, it must be heated to insure dryness, except that at intervals of one hundred feet, more or less, along the line of the street, if the Engineer shall so direct, three courses of blocks across the street will be separated by one-half inch planks. After removal of these planks, the joints will be filled with an asphalt filler as before described. The surface of the paving will then be covered with one-half inch of clean, fine sand.

Split blocks can only be used to break joints in starting courses or in making closures, but in no case shall less than a half block be used, except in closures.

The bidder must deposit with the Engineer, if requested, at the time of making his bid, samples in suitable boxes or bars, of the following materials intended to be used, properly labeled with the name or brand of the contents, viz:

Sample of not less than one pound of creosote oil.

Two blocks each of both treated and untreated blocks.

Each labeled with the name of the bidder and the name of the job on which he is a bidder.

If so shown on the plans, a one inch sand filler will be substituted for the cement bed.

Watson's Bridge Specifications
Section U.

Standard Specifications for Portland Cement

GENERAL CONDITIONS

All cement shall be inspected.

Cement may be inspected either at the place of manufacture or on the work.

In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building, having the floor properly blocked or raised from the ground.

The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

Every facility shall be provided by the Contractor, and a period of at least twelve days allowed for the inspection and necessary tests.

Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto.

The acceptance or rejection shall be based on the following requirements.

PORTLAND CEMENT

Definition. This term is applied to the finely pulverized product resulting from calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination.

SPECIFIC GRAVITY.

The specific gravity of the cement, thoroughly dried at 100° C. shall be not less than 3.10.

FINENESS.

It shall leave by weight a residue of not more than 8 per cent on the No. 100, and not more than 25 percent on the No. 200 sieve.

TIME OF SETTING.

It shall develop initial set in not less than thirty minutes but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

The minimum requirements for tensile strength for briquettes one inch square in section, shall be within the following limits, and shall show no retrogression in strength within the periods specified. (For example the minimum requirement for the twenty-four hour neat cement test should be some specified value within the limits of 150 and 200 lbs., and so on for each period stated.)

NEAT CEMENT.

Age: 24 hours in moist air; strength, 175 lbs.
Age: 7 days (1 day in moist air, 6 days in water); strength, 500 lbs.
Age: 28 days (1 day in moist air, 27 days in water); strength, 600 lbs.

ONE PART CEMENT, THREE PARTS SAND.

Age: 7 days (1 day in moist air, 6 days in water); strength 150 lbs.
Age: 28 days (1 day in moist air, 27 days in water); strength, 200 lbs.

CONSTANCY OF VOLUME.

Pats of neat cement about three inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

A pat is then kept in air in normal temperature and observed at intervals for at least 28 days.

Another is kept in water, maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

These pats to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

SULPHURIC ACID AND MAGNESIA.

The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid, nor more than 4 per cent of magnesia (MgO).

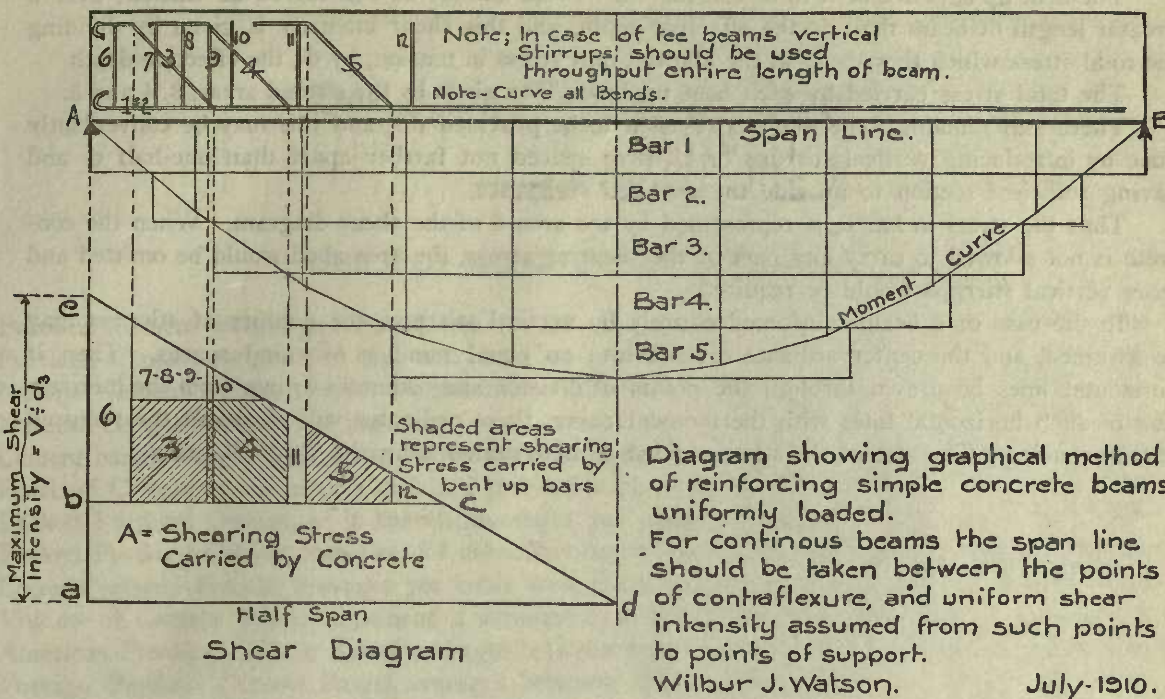

Fig a.

The above diagram, Fig. a, illustrates a practical method of determining graphically the proper spacing of shear bars in a simple beam uniformly loaded.

In proportioning Reinforced Concrete Beams, it is usually desirable to bend up part of the main reinforcing bars to assist in resistance to web tension. The points at which it is allowable to bend up these bars without impairing their efficiency as main tension members is best determined by constructing a moment diagram, in which the ordinates represent bending moments. In the case of a uniformly loaded beam it is customary to compute only the center, or maximum moment, and a convenient method of constructing the moment parabola for such cases is to divide the span line into ten equal spaces, then the vertical ordinates drawn from the dividing points of these ten spaces will be equal respectively to 100, 96, 84, 64 and 36 per cent of the center ordinate.

For beams loaded with concentrated loads the bending moments at the point of application of the loads should be computed, and the moment polygon drawn.

If the intensity shear diagram be also drawn, we have a graphical representation of the amount of shearing stress (or diagonal tension) to be provided for.

Some specifications and building codes allow the assumption that the concrete itself may take part of the shearing stress.

Multiplying the allowed unit diagonal tension stress in the concrete by the width of the beam gives the shear intensity which the concrete itself may take, represented in the diagram by the area abcd.

The bent up bars are next to be considered. These cannot be considered as efficient over a greater length of beam than d_3, the effective depth, and this shear intensity is given by dividing the total stress which they carry at the allowed unit stress in tension, by d_3, the effective depth.

The total stress carried by each bent up bar is then given by the shaded areas, 3, 4 and 5.

There still remains some diagonal tension to be provided for, and this may be conveniently done by introducing vertical stirrups or U bars; spaced not farther apart than one-half d_3 and having sufficient section to provide the required resistance.

Thus the stress in bar 6, is represented by the area 6 of the shear diagram. When the concrete is not allowed to carry any part of the shearing stress, the area abcd would be omitted and more vertical stirrups would be required.

In the case of a beam reinforced entirely by vertical stirrups, the number of stirrups may be assumed, and the center ordinate divided into an equal number of equal spaces. Then if horizontal lines be drawn through the points of division and ordinates drawn from the intersection of such horizontal lines with the moment curve, these ordinates will represent the required stirrup spacing. The size of the stirrups must be determined from the shear diagram.

Watson's Bridge Specifications
Section W.

Designing Tables and Data

TABLE OF WEIGHTS AND VOLUMES

Portland Cement weighs per barrel, net	376 lbs.
Portland Cement weighs per bag, net	94 lbs.
Natural Cement weighs per barrel, net	282 lbs.
Natural Cement weighs per bag, net	94 lbs.
Cement barrel weighs from 15 to 30 lbs. averaging about	20 lbs.
Portland Cement is assumed in standard proportioning to weigh per cubit foot	100 lbs.
Packed Portland Cement, as in barrels, averages per cubic foot about	115 lbs.
Packed Portland Cement based on 3.5 cubic feet barrel contents weighs per cubic foot	108½ lbs.
Loose Portland Cement averages per cubic foot about	92 lbs.
Volume of Cement Barrel, if cement is assumed to weigh 100 lbs. per cubic foot	3.8 cu. ft.
American Portland Cement Barrel averages between heads about	3.5 cu. ft.
Foreign Portland Cement Barrel averages between heads about	3.25 cu. ft.
Natural Cement Barrel averages between heads about	3.75 cu. ft.
Weight of Paste made from neat Portland Cement averages per cubic foot about	1.37 lbs.
Volume of Paste made from 100 lbs. of neat Portland Cement averages about	0.86 cu. ft.
Volume of Paste made from one barrel of neat Portland Cement averages about	3.2 cu. ft.
Weight of Portland Cement Mortar in proportions 1:2½ averages per cubic foot	135 lbs.
Weight of Concrete and Mortar varies with the proportions as well as with the materials of which it is composed.	
Weight of Portland Cement Concrete per cubic foot.	
Cinder Concrete averages	112 lbs.
Conglomerate Concrete averages	150 lbs.
Slag Concrete averages	134 lbs.
Gravel Concrete averages	150 lbs.
Limestone Concrete averages	148 lbs.
Sandstone Concrete averages	143 lbs.
Trap Concrete averages	155 lbs.

Loose Unrammed Concrete is 5% to 25% lighter than concrete in place, varying with the consistency.

TABLE OF WEIGHTS AND ANGLES OF REPOSE VALUES OF r (FOR THE MOST PART FROM "CAMBRIA STEEL").

Name.	Approximate Values of Φ	Average Weight in Lbs. per Cu. Ft.
Anthracite, broken, of any size, loose	27°	52-56
" " moderately shaken	...	56-60
" solid	...	93.5
Ashes of soft coal, solidly packed	...	40-45
Cement, hydraulic, Am. ground, loose	...	56
" " Cumberland, loose	...	65
" " " thoroughly shaken	...	85
" " English Portland	...	81-102
" " American Portland, loose	...	88
" " " " thoroughly shaken	15°	110
Coal, bituminous, solid	...	84
" " broken, of any size, loose	35°	47-52
" " " moderately shaken	...	51-56
Coke, loose, good quality	...	23-32
Earth, common loam, dry, loose	...	72-80
" " " " shaken	40°	82-92
" " " " rammed	...	90-100
" " " slightly moist, loose	45°	70-76
" " " more moist, loose	...	66-68
" " " " " shaken	...	75-90
" " " " " packed	...	90-100
" " " as soft flowing mud	...	104-112
The same well pressed	...	110-120
Gravel, about the same as sand	...	....
Mud, dry, close	...	80-110
" wet, moderately pressed	...	110-130
" " fluid	...	104-120
Petroleum	0°	54.8
Salt, coarse	...	45
Sand of pure quartz, dry, loose	35°	90-106
" " " " voids full of water	30°	118-129
" " " " very large grains	35°(?)	117
Water, pure	0°	62.417

*ANGLES AND COEFFICIENTS OF FRICTION.

	tan Φ	Φ	$\frac{1}{\tan \Phi}$
Dry masonry and brick work	0.6 to 0.7	31° to 35°	1.67 to 1.43
Masonry and brick work with damp mortar	0.74	36½°	1.35
Timber on stone	about 0.4	22°	2.5
Iron on stone	0.7 to 0.3	35° to 16⅔°	1.43 to 3.33
Timber on timber	0.5 " 0.2	26½° " 11⅓°	2 " 5
Timber on metals	0.6 " 0.2	31° " 11⅓°	1.67 " 5
Metals on metals	0.25 " 0.15	14° " 8½°	4 " 6.67
Masonry on dry clay	0.51	27°	1.96
Masonry on moist clay	0.33	18¼°	3.
Earth on earth	0.25 to 1.0	14° to 45°	4 to 1
Earth on earth, dry sand, clay, and mixed earth	0.38 " 0.75	21° " 37°	2.63 " 1.33
Earth on earth, damp clay	1.0	45°	1
Earth on earth, wet clay	0.31	17°	3.23
Earth on earth, shingle and gravel	0.81	39° to 48°	1.23 to 0.9

*From Rankine's Applied Mechanics.

Proportions of Mixture			Material For 1 Cu. Yd. Concrete								
			Gravel 3/4" & Under			Stone 1" & under Dust screened out.			Stone 2½" & under Dust screened out.		
Cement	Sand	Stone	Cement Bbls.	Sand Yds.	Stone Yds.	Cement Bbls.	Sand Yds.	Stone Yds.	Cement Bbls.	Sand Yds.	Stone Yds.
1	2	3	1.54	0.47	0.73	1.70	0.52	0.77	1.73	0.53	0.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2½	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	0.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	0.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	0.84	.38	.89	0.91	.42	.97	0.92	.42	.98
1	4	6	0.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	0.77	.47	.81	.83	.51	.89	.84	.51	90
1	4	8	0.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	0.65	.40	.89	.71	.43	.97	.73	.44	1.01

RETAINING WALL EARTH PRESSURES

HEIGHT	$\theta=0°$; $\phi=45°$		$\theta=\phi=45°$		$\theta=0°$; $\phi=\tan^{-1}\frac{1}{1.5}$		$\theta=\phi=\tan^{-1}\frac{1}{1.5}$		$\theta=0°$; $\phi=\tan^{-1}\frac{1}{2}$		$\theta=\phi=\tan^{-1}\frac{1}{2}$	
	UNIT PRESS.	TOTAL PRESS.	UNIT PRESS.	TOTAL PRESS.	UNIT PRESS.	TOTAL PRESS.	UNIT PRESS.	TOTAL PRESS.	UNIT PRESS.	TOTAL PRESS.	UNIT PRESS.	TOTAL PRESS.
6	103	309	424	1273	172	516	499	1498	229	688	536	1610
8	137	549	566	2263	229	917	666	2663	306	1222	716	2862
10	172	858	707	3536	286	1432	832	4160	382	1910	894	4472
12	206	1235	849	5091	344	2062	998	5990	458	2750	1073	6440
14	240	1681	990	6930	401	2807	1165	8154	535	3743	1252	8765
16	275	2196	1131	9051	458	3666	1331	10650	611	4889	1431	11448
18	309	2799	1273	11455	516	4640	1498	13479	688	6188	1610	14490
20	343	3431	1414	14142	573	5728	1664	16641	764	7639	1789	17889
22	377	4152	1556	17112	630	6931	1831	20136	840	9244	1968	21645
24	412	4941	1697	20364	687	8249	1997	23963	917	11000	2147	25640
26	446	5779	1838	23900	745	9681	2163	28123	993	12910	2326	30232
28	480	6726	1980	27719	802	11228	2330	32616	1070	14973	2504	35062
30	515	7721	2121	31820	859	12889	2496	37442	1146	17189	2683	40249
32	549	8784	2263	36204	917	14665	2663	42601	1222	19557	2862	45795
34	583	9917	2404	40871	974	16555	2829	48092	1299	22078	3041	51698
36	618	11118	2546	45821	1031	18560	2995	53917	1375	24752	3220	57959
38	652	12387	2687	51053	1088	20680	3162	60074	1451	27578	3399	64578
40	686	13726	2828	56569	1146	22914	3328	66564	1528	30558	3578	71554

Note:- Values were computed from Rankine's formulae for earth pressure.
Direction of pressure is parallel to surface of earth. θ= angle of surcharge. ϕ= angle of repose.
Weight of earth assumed at 100 lbs. per cubic foot.

COOPER'S STANDARD LOADING FOR RAILROAD BRIDGES

DISTANCES IN FEET

Class	8	5	5	5	9	5	6	5	8	8	5	5	5	9	5	6	5	5	Uniform Load
E 60	30000	60000	60000	60000	60000	39000	39000	39000	39000	30000	60000	60000	60000	60000	39000	39000	39000	39000	6000 lbs per lin. ft
E 40	20000	40000	40000	40000	40000	26000	26000	26000	26000	20000	40000	40000	40000	40000	26000	26000	26000	26000	4000 lbs per lin. ft.

Loads given are axle loads

STANDARD LOADING FOR ELECTRIC RAILWAY BRIDGES

DISTANCES IN FEET

Class	6	16	6	16	6	16	6	
100 Ton Cars	50000	50000	50000	50000	50000	50000	50000	50000
50 Ton Cars	25000	25000	25000	25000	25000	25000	25000	25000

Loads given are axle loads
For loadings intermediate between these use proportional loads.

WORKING UNIT STRESSES FOR TIMBER.

Group	Quality	Transverse Loads			End Bearing			Columns. Length ≦ 12 × Side			Bearing Across Fibre			Shear Across Fibre			Shear Along Fibre			Working Modulus of Elasticity
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
No. 1 Long Leaf Yellow Pine, Cuban Pine	No 1	2000	1600	1200	1650	1350	1000	1150	950	700	500	400	300	2000	1600	1200	250	200	150	750000
	No 2	1350	1050	800	1100	900	650	750	600	450	350	250	200	1350	1050	800	200	150	100	
No. 2 White Oak, Post Oak	No 1	1850	1450	1100	1650	1350	1000	1150	950	700	750	600	450	1650	1350	1000	350	275	200	600000
	No 2	1250	1000	750	1100	900	650	750	600	450	500	400	300	1100	900	650	250	200	150	
No. 3 Short Leaf Pine, Red and Black Oaks, Douglas (Oregon) Fir	No 1	1650	1350	1000	1350	1050	800	1000	800	600	350	250	200	1850	1450	1100	250	200	150	600000
	No 2	1100	900	650	900	700	550	650	550	400	250	200	150	1250	1000	750	200	150	100	
No. 4 White Pine, Norway (Red) Pine, Poplar, Bald Cypress, Western Hemlock (Washington Pine)	No 1	1350	1050	800	1100	900	675	850	650	500	250	200	150	1000	800	600	175	150	100	500000
	No 2	900	700	550	750	600	450	600	450	350	200	150	100	650	550	400	110	90	70	
No. 5 Eastern Hemlock, Chestnut, Tamarack, Cypress	No 1	1150	950	700	1100	850	650	850	650	500	250	200	150	650	550	400	135	105	80	500000
	No 2	750	600	450	750	600	450	600	450	350	200	150	100	450	350	250	90	75	55	
Approx. Factor of Safety		4.8	6	8	4.8	6	8	4.8	6	8										

A = For Members free from Impact and Exposure to Weather & for Timber used in Temporary Construction.
B = For Members Subject to Impact or Exposure to Weather.
C = " " " " " and " " "
When Impact is included in Total Stress, make no Allowance for it in Unit Stress.
Quality No 1 corresponds to No 1 Common Dimension Standard Yellow Pine Grading Rules.
Quality No 2 " " No 2 " " " " " " " .
Quality No 2 Includes All Green Timber.

PROPERTIES OF PLAIN STEEL RODS.

Square Rods			Size	Round Rods		
Perimeter	Weight per lineal foot	Sectional Area		Sectional Area	Weight per lineal foot	Circumference
1.00 in.	.212 lbs.	.0625 □"	1/4"	.0491 □"	.167 lbs	.785 in.
1.25 "	.333 "	.0977 "	5/16"	.0767 "	.261 "	.982 "
1.50 "	.478 "	.1406 "	3/8"	.1104 "	.375 "	1.178 "
1.75 "	.651 "	.1914 "	7/16"	.1503 "	.511 "	1.37 "
2.00 "	.850 "	.250 "	1/2"	.196 "	.668 "	1.57 "
2.25 "	1.076 "	.316 "	9/16"	.249 "	.845 "	1.76 "
2.50 "	1.328 "	.391 "	5/8"	.307 "	1.044 "	1.96 "
3.00 "	1.913 "	.563 "	3/4"	.442 "	1.502 "	2.36 "
3.50 "	2.603 "	.766 "	7/8"	.601 "	2.044 "	2.75 "
4.00 "	3.400 "	1.000 "	1"	.785 "	2.670 "	3.14 "
4.50 "	4.303 "	1.266 "	1 1/8"	.994 "	3.379 "	3.53 "
5.00 "	5.312 "	1.563 "	1 1/4"	1.227 "	4.173 "	3.93 "
5.50 "	6.428 "	1.891 "	1 3/8"	1.485 "	5.049 "	4.32 "
6.00 "	7.650 "	2.250 "	1 1/2"	1.767 "	6.008 "	4.71 "

Data Required for Designing Reinforced Concrete Bridges

1. Class of bridge desired.
2. Width of roadway.
3. Number of Street Railway tracks and distance apart.
4. Width of sidewalks.
5. Paving desired.
6. Sidewalk finish desired.
7. Clear width of openings required.
8. Number of spans required.
9. Distance from average low water level (or in the case of bridges over railroads from top of rail, or in the case of bridges over highways from grade of lower highway) to grade.
10. Depth of water at average low water level.
11. Distance from average low water level to extreme high water mark.
12. Distance from average low water level to usual high water mark.
13. Distance from average low water level to grade of adjacent bridges, if any over same stream, and also clear span of such adjacent bridges.
14. Approximate area of land in square miles drained by stream.
15. Approximate grade of stream in feet per mile.
16. Does the stream carry floating logs, debris or ice when in flood?
17. Character of bed of stream, mud, gravel, shale, or rock.
18. Character of banks of stream, height above average water level, and approximate angle of slope.
19. Character of foundations for piers or abutments at average low water.
    At five feet below low water.
    At ten feet below low water.
    At fifteen feet below low water.
    At twenty feet below low water.
20. Angle of crossing.
21. Grade of roadway, ascending north, south, east or west.
22. Approximate cost of broken stone, gravel, slag, sand and cement delivered at the bridge site.
23. Nearest railroad siding.
24. Nature of present bridge and disposition thereof.
25. Traffic maintained or diverted during construction of new bridge.
26. Sketch profile and plan of crossing.

Contract Form

Contract for ....

Bridge over ....

At ....

For ....

This agreement made ....

in the year ....

by and between ....

Party of the First Part (hereinafter designated as the Contractor) and......................
Party of the Second Part (hereinafter designated as the Owner)

Witnesseth: That the Contractor, in consideration of the agreements herein made by the Owner, agrees with the said Owner as follows:

Art. I. The Contractor shall and will provide all the materials and perform all of the labor for the construction of the works herein specified for bridge over..........................

at ....

all as shown on the drawings and described in the specifications attached hereto or on file

at ....

which drawings and specifications are identified by the signatures of the parties hereto and which are hereby made a part of this contract.

Art. II. It is understood and agreed by and between the parties hereto that the work included in this contract is to be done under the direction of the said Engineers who represent the Owners on the work, and that their decision as to the true construction and meaning of the contract and the specifications shall be final. It is also understood and agreed by and between the parties hereto that such additional drawings and explanations as may be necessary to detail and illustrate the work to be done are to be furnished by said Owner, and the Contractor agrees to conform to and abide by the same so far as they may be consistent with the purpose and intent of the drawings and specifications.

Art. III. The Engineer will also give all lines and levels necessary for the prosecution of the work and be responsible for the accuracy thereof.

Art. IV. It is further understood by the parties hereto that any or all of the drawings and specifications prepared for the purpose of this contract by the said Engineers are and remain their property and that all charges for the use of the same and for the services of the said Engineers are to be paid by said Owner.

Art. V. No alteration or modification shall be made of this contract until the price to be paid for the work or material or both under the altered or modified contract has been agreed

upon in writing and signed by the Contractor and by the Owner, and in no case shall the Contractor recover for such work or material or both in excess of the contract price, or in case the parties hereto be not able to agree upon such price, the changes or additions may be made by order of the Engineer, and the compensation therefor referred to the Arbitrators chosen as per Art. XIX.

Art. VI. Should the Contractor at any time refuse to supply a sufficiency of properly skilled workmen or of materials of the proper quality or fail in any respect to prosecute the work with promptness and diligence or fail in performance of any agreements herein contained, such refusal, neglect, or failure being certified to by the Engineer, the Owner shall be at liberty, after three days written notice to the Contractor, to provide any such labor or materials and to deduct the cost thereof from any money then due or thereafter to become due to the Contractor under this contract; and if the Engineer shall certify that such refusal, neglect or failure is sufficient ground for such action, the Owner shall also be at liberty to terminate the employment of the Contractor for the said work and to enter upon the premises and take possession for the purpose of completing the work included under this contract, of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work and to provide materials therefor; and in case of such discontinuance of the employment of the Contractor, he shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the Owner in finishing the work, such excess shall be paid by the Owner to the Contractor, but if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner. The expense incurred by the Owner as herein provided for either for furnishing the materials or for finishing the work, and any damage incurred through such default, shall be audited and certified to by the Engineer, whose certificate shall be conclusive upon the parties, subject to the Arbitration Clause.

Art. VII. Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner, of the Engineer or of any other Contractor employed upon the work by the Owner, or by damage caused by fire or other casualty for which the Contractor is not responsible, or by general strikes or lockouts caused by acts of employees, and which the Contractor is not able to prevent, then the time herein fixed for the completion of the work shall be extended for a period equivalent to the time lost by any or all of the causes aforesaid, which extended period shall be determined and fixed by the Engineer, but no such allowance shall be made unless a claim therefor is presented in writing with the Engineer within forty-eight hours of the occurrence of such delay.

Art. VIII. The Owner agrees to provide all labor and materials essential to the conduct of the work not included in this contract in such manner as not to delay its progress, and in the event of the failure so to do, thereby causing loss to the Contractor, agrees that he will reimburse the Contractor for such loss; and the Contractor agrees that if he shall delay the progress of the work so as to cause loss for which the Owner shall become liable, then he will reimburse the Owner for such loss. Should the Contractor and the Owner fail to agree as to the amount of loss comprehended in this article, the determination of the amount shall be referred to arbitration as provided in Article XIX.

Art. IX. It is hereby mutually agreed between the parties hereto that the sum to be paid by the Owner to the Contractor for such work or material shall be as follows: (In case of a unit price bid, insert here the different items and unit prices for same.)

....

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Subject to additions and deductions as hereinafter provided and that such sums shall be paid the Contractor by the Owner in current funds and only upon certificates of the Engineers, as follows:

At periods not less than thirty days apart, on the request of the Contractor, the Engineers will make estimates of the value of material furnished and labor performed; and the amount of such estimates less ten (10) per cent will be paid the Contractor by the Owner within ten (10) days after such estimate has been presented for payment.

The final payment shall be made in sixty (60) days after the completion of the work included in this contract and the acceptance thereof in writing by the Owner and all payments shall be due when certificates for the same shall be issued.

Art. IX (alternate). It is hereby mutually agreed between the parties hereto that the sum to be paid by the Owner to the Contractor for such work or material shall be as follows:

....

....

....

....

Subject to additions and deductions as hereinafter provided and that such sums shall be paid the Contractor by the Owner in current funds and only upon certificate of the Engineers.

The final payment shall be made in thirty days after the completion of the work included in this contract and the acceptance thereof in writing by the Owner, and all payments shall be due when certificates for the same are issued.

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Art. X. It is hereby mutually agreed between the parties hereto that the use of the completed work is worth..................................dollars per day to the Owner, after ....and that this sum shall be deducted from the contract price, for each day intervening between such date and the date of completion, as liquidated damages for the deprivation of the use of the completed work.

Art. XI. It is also hereby agreed between the parties hereto, that the use of the completed work is worth....................................dollars per day to the Owner, before ....and that this sum shall be added to the contract price for each day that the work shall have been completed, prior to such specified date.

....

....

Art. XII. If at any time there shall be evidence of any lien or claims for which, if established, the Owner of the said premises might become liable and which is chargeable to the Contractor, the Owner shall have the right to retain out of any payment then due or thereafter to become due, an amount sufficient to completely indemnify it against such lien or claims.

Art. XIII. It is further mutually agreed between the parties hereto, that no certificate given or payment made under this contract, except the final certificate or final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials.

Art. XIV. All royalties for patents or claims for the infringement thereof that may be involved in the construction or use of this work shall be included in the contract amount and the Contractor shall satisfy all demands that may be made at any time for such and be liable for any damage or claims for infringement thereof, and the Contractor will at his own expense defend any and all suits or proceedings that may be instituted against the Owner for the infringement of any patent or patents involved in the work, and in case of an award of damages the Contractor will pay such damages.

Final payment will not be made while any such suits or claims remain unsettled.

Art. XV. No part of the work shall be sublet, nor shall the contract for the whole or any portion of the work be assigned without written consent of the Owner.

Art. XVI. The Contractor shall give to the proper authorities all requisite notices relating to the work in his charge and shall conform to all laws and ordinances affecting same, and shall obtain all official permits and licenses required, and pay all proper fees for same, and he shall pay for any other legal charges from city, county, state or federal officers, including all inspection charges imposed by the Federal or local Government.

Art. XVII. The work shall be suitably protected by red cautionary lights at night and by watchmen if necessary.

Art. XVIII. The execution of the work will be entirely at the Contractor's risk and he will be liable for its safety. The Contractor will be liable for all cases of personal injuries which may occur during the progress of the work.

Art. XIX. In case the work be not completed at the dates specified it is mutually agreed between the parties hereto that the Contractor shall pay all damages and expenses to which the Owner may be subjected by reason of such delay in the compensation of the work, including all expense of additional engineering and supervision, to compensate the Owner for the deprivation of the use of the completed work, and also the amount of liquidated damages provided for herein.

Art. XX. In case the Owner and the Contractor fail to agree in relation to matters of payment, allowance or loss referred to, or should either of them dissent from the decisions of the Engineer referred to, which dissent shall have been filed in writing with the Engineer within ten days of the announcement of such decision, then the matter shall be referred to a Board of Arbitration to consist of one person selected by the Owner and one person selected by the Contractor, these two to select a third. The decision of any two of this Board shall be final and binding on both parties hereto. Each party shall pay one-half of the expenses of such reference.

Art. XXI. The intent of the plans and specifications which accompany this contract is to describe a complete piece of work and the Contractor agrees to furnish, at his own expense, all parts and details not specifically shown or mentioned therein, but which may be necessary to the completion of the works specified and to perform all labor necessary to complete the works shown.

....

Party of the First Part (Contractor)

....

Party of the Second Part (Owner)